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# Numerical forecasting of clear air turbulence

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# NUMERICAL FORECASTING OF CLEAR AIR TURBULENCE

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# CLEAR AIR TURBULENCE

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ABSTRACT

There is much disagreement as to (a) what causes clear air turbulence (turbulence which is not in or near convective clouds and is above 15,000 feet in altitude) and (b) which meteorological parameters can be used to detect and forecast its occurrence. The approach to this problem has been to relate not one parameter to clear air turbulence but various parameters. By summing these parameters areas can be defined where there is a high probability of encountering clear air turbulence. Each parameter has been based on a statistical study which found a relationship with clear air turbulence. The parameters used were horizontal and vertical shear, curvature, kinetic energy and their derivatives.

The numerical forecasting program proposed here can be extended to the stratosphere when more reliable height and temperature fields are available. This program will have much more significance when intermediate forecast height fields, temperature fields and a grid of much smaller mesh length are available.

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## 1. INTRODUCTION

The phenomenon of clear air turbulence (henceforth denoted as CAT) appears to consist of random three dimensional eddies that occur in certain confined regions of the atmosphere. This phenomenon was first recognized in the early 1940's as "air pockets", and has gained in importance and depth of study with the development of fast-flying swept wing and delta winged aircraft. It is of prime importance to the aviation industry because it affects the safety and comfort of passengers and crew, as well as operational costs. There have been several cases where loss of control of aircraft, structural damage, passenger and crew injuries (even deaths) have resulted from CAT.

Aircraft manufacturers and the airlines are interested in CAT in order to determine the strength of airframe design so that it can be built to withstand all degrees of turbulence. Planning of supersonic transport aircraft is considering the effects of this unexpected turbulence occurring at any flight level in the atmosphere. Therefore, it becomes an even greater operational problem in the era of future design of SST aircraft as to cost, safety and comfort. CAT is usually less intense than turbulence encountered in thunderstorms [1]. CAT may be considered at times more dangerous than "thunderstorm turbulence" as it usually occurs with no visible warning.

The various military agencies are deeply concerned with the understanding of CAT and its prediction so they may be better prepared to take it into account operationally in all areas of the world. Scientists are highly interested in CAT because it is a phenomenon of our environment that is not clearly understood. We are faced with the problem of having to rely on mesoscale data while the phenomenon is of a microscale. Because of the great differences in scales involved in the forecasting

problem, isolated patches of CAT (in either space or time) are very difficult to identify. It is the intent of this paper to develop a numerical forecasting system of CAT whereby an empirical approach has been used to accomplish this end.

## 2. DATA COLLECTION

The nature of clear air turbulence, its physics and its meteorology, are still not completely understood. More mesoscale (2km to 100km horizontal distance) and microscale (less than 2km) studies must be made concerning the causes and generation of CAT. Any improvement in forecasting skill that may be realized by this study will probably result from increased mesoscale input data into the forecast problem. The only mesoscale measurements available operationally at this time which concern the problem are rawinsonde data that give a nearly continuous measurement in the vertical of wind, pressure, temperature and humidity from the surface to above 30km in altitude, and satellite cloud pictures that delineate cloud structures down to a scale of about 3km.

The usual definition of CAT is "atmospheric turbulence which is not in or near convective clouds, including thunderstorms, and is not below 15,000 feet in altitude". (4) Thus, mechanical turbulence induced by rough terrain is excluded. It is realized that this is an extremely arbitrary definition resulting from a desire to simplify pilot reporting procedures.

Turbulence intensities are, at present, designated as light, moderate, severe and extreme. In recent years several definitions of the four categories of turbulence have been proposed. The current definitions in official use were developed by the National Advisory Committee for Aeronautics (NACA) Subcommittee on Meteorological Problems (1957). See Table 1.

There are few quantitative measurements of atmospheric turbulence at any scale. The bulk of the aircraft turbulence data available is based upon the four categories stated in Table 1, (4) ; and, consequently is highly subjective and qualitative in nature. Included in the factors that affect the subjective decision of the pilot when reporting turbulence are the wing loading, the aircraft's speed and attitude, the pilot's training, experience, and his psychological reactions (1) .

Objective criteria for turbulence reporting must wait until more measurements are made of the conditions existing in the turbulent eddies, and until cockpit instrumentation includes a gust load or turbulence indicator.

Much time, effort and financial support have been expended in this country by the government, the aircraft industry, and private and public research facilities to investigate the problem of clear air turbulence and to find a good approach leading to a solution to this problem. This research has gone forward in three broad categories: first, research concerning the correlation of CAT with macroscale, mesoscale, and/or microscale atmospheric measurements; second, research into instrumentation for the detection of CAT sufficiently far in advance of the aircraft to allow evasive measures (6) and third, research by military and airline organizations concerning the operational aspects of CAT.

Various projects such as HICAT, ALLCAT, and TOPCAT have been undertaken to study clear air turbulence. The problems encountered were many but the results showed that it was indeed possible, with suitable instrumentation, to find, track and record CAT. The use of constant level ballons and doppler radar to detect CAT has met with some success, but again the lack of detail necessary in CAT studies leaves much to be desired.

Measurements of the microstructure, which contains the perturbations of CAT dimensions (100 to 500 meter wavelength), have been taken by specially instrumented aircraft. Until recently the aircraft itself was used as a sensor to measure atmospheric gusts from the aircraft acceleration data. The Air Force realized the danger of relying solely on the acceleration response of the U-2 aircraft as a measure of turbulence at high altitudes. A full knowledge of the aircraft's response to turbulence over a wide range of wavelengths is required for meaningful interpretation of such data. This procedure usually gives reliable results at short wavelengths up to a few hundred meters. At long wavelengths, this instrumentation becomes less sensitive. Accelerations in longer waves are usually small and can be masked by pilot induced aircraft motions.

A supersonic or hypersonic craft of some radical shape, flying four to ten times the speed of the U-2, will obviously have a somewhat different response to turbulence than the U-2. An aircraft flying at these high speeds would be affected much more by longer turbulence wavelengths and less by the shorter.

As pointed out earlier, the meteorologist has few direct measurements of turbulence intensities and must depend upon the accuracy of the intensities reported by pilots. In our study, we used the Colson monthly turbulence summaries which were obtained from the Air Force 3rd Weather Wing at Offutt AFB, Omaha, Neb. This report suited our needs most closely because the CAT reports were detailed as to location, time, altitude and intensity. In the period used in our study, December 1964 through March 1965, there were no less than 3670 CAT reports. The

reports were located over the United States and extended from about 15,000 feet to over 45,000 feet. The data were collected from military, civilian and private aircraft. They are, as mentioned before, quite subjective.

In the course of this paper three time periods or intervals will be used. It is important to establish at this point which periods were used and for what purpose.

A four month period (December 1964 through March 1965) is used for the research program during which several fields were constructed. Patterns of fields of different meteorological parameters were sometimes similar. Then all but one of them were dropped in our further investigations. In this way only three of the original seven parameters were retained.

The three day period (10 - 12 March, 1965) was used for a verification or correlation study. During this period of time a comparison was made to find out how many times CAT actually occurred in areas where it was predicted.

Finally, 23 February 1965 was arbitrarily chosen from the four month period and used only for illustrating the various fields and parameters used in the research program.

## 3. THE CLEAR AIR TURBULENCE STUDY

Clear air turbulence (CAT) is a microscale phenomenon (less than 2 kilometers in horizontal extent) but the conditions which are symptomatic of its existence are of snyoptic scale. Therefore, synoptic scale parameters may be used to determine areas where CAT could occur, that is forecasting areas where there is a high probability of CAT.

From various reports and their contradicaions it appears that no single parameter can detect CAT. Certain parameters can detect the possibility of CAT in some synoptic situations but fail in others.

The approach used in this paper was to take statistical studies made by previous investigators and to use the basic parameters which they related to CAT (2,3,5,7,8). If the magnitude of any one parameter becomes large or the sum of various parameters becomes large then there is a high probability of CAT in that area. Therefore, the problem is not one of forecasting actual CAT but rather to forecast areas of high and low probability of encountering CAT. In this way flights may be planned so as to expect least CAT.

The research program consisted of computing the equations shown in Appendix A. These equations were computed using the CDC 1604 digital computer. The program was written utilizing symbolic coded relocatable assembly program (SCRAP). It was necessary to use fixed point fractional numbers in order that Fleet Numerical Weather Facility (FNWF) subroutines could be used. All finite differences were computed using standard FNWF mesh length of 381 kilometers true at 60 degrees north latitude. There are no time derivatives in the program. The research reported here is accomplished using analytical fields. Operational use would employ

forecast fields. Results would naturally not have been as good if -cast fields were used in this research. "Prog 24 hours" printed at the bottom of each field represents the practical forecast interval to be used operationally.

The research program was written to compute CAT in three layers 500 to 300, 300 to 200, and 200 to 100 millibars. Computations were not made for the third layer since 100 millibar fields were not available.

The research program was written to compute on the entire 63 x 63 FNWF grid of the northern hemisphere. A boundary condition of zero was used for the outside rows and columns. The print routines are 22 x 22 extracts of the United States starting at FNWF grid point J008, I018. The latitude and longitude coordinates of the four corners of the printed fields starting with the lower left corner proceeding clockwise are: 9.1N 109.5W, 44.5N 165.5W, 57.7N 3.1E, 13.0N 58.8W.

All printed fields are pure numbers and have no dimensional meaning. All scaled outputs have been shifted to the left end of the register and the first three numbers with sign bit are printed out in decimal. Grid points can take on values from -999 to +999 except those fields which have been made all positive. The decimal point does not appear on the printed fields. Therefore, the printed grid point values are from -999 to +999.

In the research program the capital letters refer to the parameter as computed from the data. The small case letters serving as exponents represent the number of times and direction the register has to be shifted in order to place the significant portion into the first three numbers. Therefore, the two with exponents represent the scaling coefficient. Since the computations were in fixed point fractional all

printouts had to be shifted so as not to exceed one at any grid point in the field. Exceeding one would result in a meaningless value at that particular grid point. In addition the entire field had to be kept large enough so that patterns could exist and not be at or near zero throughout the field. Since these fields are summed they must be small enough so as not to cause the summation field to exceed one at any grid point.

The research program was run for thirty-six days during December 1964 and January, February, and March 1965. The thirty-six days were chosen because they were the most active in CAT reports during the four month period. In other words, there were more reports by pilots encountering CAT on these particular days. In order to show an example of each field printed out by the research program the time 00Z 23 FEB 65 was arbitrarily selected. These fields appear in Appendix C. Each field was produced by an individual term which will be described as follows:

THE FIRST TERM OF THE RESEARCH PROGRAM (APPENDIX A)

The First Term is $2^a$ A where A is the Laplacian of absolute vortisity. When this term is negative there is a local maximum of absolute vorticity meaning it is larger at that grid point than the average of the surrounding grid points. Therefore, the cyclonic curvature or cyclonic shear or both are relatively large at that grid point. This should correspond to the cold side of the jet especially in throughs. According to Endlich and McLean (1) there is a greater percentage of CAT on the cold side of the jet. Also according to Harrison (2) there is a strong tendency for moderate to severe CAT to be associated with trough lines.

This term was computed for the layer by first calculating the absolute vorticity of the upper and lower level D fields. The Laplacian was then taken of each field and a vertical average made of the upper and lower levels to obtain the Laplacian of vorticity of the layer.

This parameter has depicted most of the CAT associated with the trough over the western United States. The severe CAT near New Orleans is in an area of very large negative numbers. The field is contoured at intervals of 100 with the origin at zero.

THE SECOND TERM

The Second Term is $2^b$ B where B is the absolute value of the vertical change in the vector thermal wind. One of the parameters which Lake's (7) statistical testing indicated was associated with CAT was the vertical gradient of wind shear. As shown by Richardson (9) the thermal wind shear is proportional to the gradient of static stability.

The u and v components of the thermal wind were computed from the upper and lower level temperature fields. The difference between the upper and lower level values of the u component was found and each difference was squared. This was also done for the v component. The square root of the sum of the squared differences gives the magnitude of the vector difference. According to Endlich and McLean (3) the largest values of the thermal wind shear appear on the warm side of the jet. This was found to be true throughout the four months. The contour interval for this field is 25 and the origin is zero.

THE THIRD TERM

The Third Term is $2^c$ C where C is one half the geostrophic wind velocity squared. C therefore represents the specific kinetic energy or in other words the kinetic energy per unit mass.

Clem (2) found that most cases of moderate to severe CAT were associated with areas of isotach maxima.

This term was computed for the layer by calculating the u and v components of the geostrophic wind at the upper and lower levels. The upper and lower level u components were vertically averaged to obtain an average u component for the layer. The average v component for the layer was obtained by a similar process. The magnitude of the velocity squared is just the sum of the squared components.

In the research program this field is contoured at intervals of 100 with the origin at zero. Contoured at this interval the kinetic energy field clearly depicts the isotach maxima regions. The kinetic energy field in Appendix C shows this field depicting the CAT in the western part of the United States occurring in areas of relatively large wind speeds. The kinetic energy field fails to indicate the severe CAT near New Orleans because it occurs in an area of relatively light winds.

THE FOURTH TERM

The Fourth Term is $2^d$ D where D is the absolute value of the derivative of the kinetic energy with respect to pressure.

Lake's (7) statistical testing indicated that the gust intensities are related to the vertical gradients of horizontal kinetic energy. This term was computed for the layer by first calculating the velocity squared at the upper and lower levels. The vertical gradient for the layer was then obtained by computing the difference between the upper and lower level values of the velocity squared. The absolute value was taken so as to have all values positive. CAT should be associated with

large values of this field. Large values of this field were found only in areas of large values of kinetic energy. This field was therefore redundant and was eliminated from the CAT forecast program. The contour interval was 100 with the origin at zero.

THE FIFTH TERM

The Fifth Term is $2^e$ E where E is the absolute value of the Laplacian of kinetic energy. The statistical survey made by Endlich and McLean (3) shows the maximum occurrence of CAT along the edges of the isotach maxima. The Laplacian of kinetic energy shows large horizontal changes in kinetic energy, both positive and negative. Therefore the absolute value of the term is taken in order to give only positive numbers. The contour interval was 25 with the origin at zero.

This term was introduced to depict the areas of large horizontal change in kinetic energy. However, there was no relationship with reported CAT. This field was therefore eliminated from the CAT forecast program.

THE SIXTH TERM

At this point in the research program it was necessary to sum the first five terms due to computer memory space. This term, referred to as KAT1, was the Sixth Term. The contour interval was 250 with the origin at zero. It was found that this term did not supply significantly new information since it was dominated by the kinetic energy and the two associated terms.

THE SEVENTH TERM

The Seventh Term is $2^f$ F where F is the Jacobian of temperature and omega (component of the wind normal to the pressure surface). This

term was developed by Dr. Moore of Douglas Aircraft and Dr. Krishnamurti (8). The latter was associated at that time with the University of California, Los Angeles and consultant to Douglas Aircraft. The term was developed as the Jacobian of temperature and three dimensional divergence. As shown in their paper this is proportional to the negative of the Jacobian of temperature and omega. This term was computed for the lower level of each layer in the research program. The contour interval for this term was 100 with the origin at zero. In this program no significant relationship was found with large negative or positive numbers over the four month period. This term was therefore eliminated from the CAT forecast program.

THE EIGHTH TERM

The Eighth Term is $2^g$ G where G is the absolute value of horizontal divergence. It was computed by taking the derivative of omega with respect to pressure. As previously stated the entrance and exit regions of isotach maxima areas have been found to be associated with CAT. These areas are also associated with horizontal convergence at the entrance and divergence at the exit regions. Therefore the absolute value of the change in omega with pressure represents the convergence and divergence in the layer parallel to the pressure surfaces.

This term was computed by subtracting the lower level omega value from the upper level omega value at each grid point. Areas of convergence and divergence of the height field are quite vividly depicted by the divergence field. No significant relationship was found between the divergence field and the CAT occurrences, therefore, it was eliminated from the CAT forecast program.

THE NINTH TERM

The Ninth Term was KAT2,the summation of all previous terms. No significant relationship was found with CAT occurrences since several terms tended to cancel each other out.

The program then goes into the second layer from 300 to 200 millibars. All terms were computed and scaled the same, except the divergence term. It could not be computed because the 200 millibar omega field was not available.

The third layer from 200 to 100 millibars could not be run for these time periods since the 100 millibar fields were not available. There were very few CAT reports above 200 millibars, therefore, the loss was insignificant.

In all three layers the lower level height field is printed out first. This gives a general impression of the synoptic situation and renders more significance to the patterns developed in the other fields. The contour interval for the 500 millibar field is 60 meters with the origin at 5580 meters. The contour interval for the 300 millibar field is 120 meters with the origin at 9120 meters. The contour interval for the 200 millibar field is 120 meters with the origin at 11,760 meters.

The CAT forecast program appears in Appendix D. The first three terms of the research program are used with minor changes. In the first term "a" is changed to minus one and the contour interval has been changed to 150 to give better defined patterns. The second term has been used unchanged. The third term is unchanged except for the contour interval which was changed to 50 to increase the pattern size. The KAT field itself is the summation of these three terms and gives quite reasonable patterns and pattern sizes.

The pattern area depicting a high probability of CAT would necessarily be larger during a more active CAT period. The most active part of the year was the four month period December 1964, January, February, and March 1965. During these months the most active three day period was the tenth through the twelfth of March 1965. Therefore the KAT fields have quite large pattern sizes in Appendix E since they represent the most active three days of the year. The KAT field patterns were smaller for less active periods. The total area covered by these patterns is much less in the KAT field than in the other three parameter fields.

This is exactly what was attempted in order to obtain optimum size of the forecasted danger areas. If the KAT field patterns are too large, flights will be rerouted unnecessarily. On the other hand, if the KAT field patterns are too small, there is a real danger of CAT occurring outside these areas. Therefore, the restraint of the KAT field patterns is necessary in order to have an operationally useable product.

## 4. DISCUSSION AND RECOMMENDATION FOR FUTURE STUDIES

The period used in this paper was chosen because of the largest number of reported CAT occurrences. Of the four month period (December 1964, January, February and March 1965) there were scattered periods where a large number of occurrences were reported. This four-month period was used to determine which parameters were best suited for forecasting purposes. The three-day period of 10-12 March 1965 was selected for a correlation study in order to find out how successful our forecast method is. Tables 2, 3, and 4 show the various fields used and the resultant KAT field for the $10^{th}$, $11^{th}$ and $12^{th}$ of March 1965.

The use of the term "percent correlation" as used in this study does not mean to imply a statistical correlation. The ideal forecast verification makes use of those cases where CAT is forecast, but does not occur, and where CAT is not forecast and does not occur. In our study it was impossible to take those cases quantitatively into account. Therefore, it is to be understood that "correlation" as used in this study was a general comparison of those reported CAT occurrences that fell within the delineated area of high probability of CAT against those that did not. For example, if there were ten reported CAT occurrences for a given layer and time period and six of these reports fell inside or on the line delineating the CAT area and four reports fell outside the area, then for that field, layer and time period we would list it as six occurrences correlated or a sixty percent correlation.

Listed are the names of the fields, the number of occurrences of CAT for each field and the percent correlation by field. Also shown are the number of occurrences and the number of occurrences that correlated by field and CAT intensity.

After combining the Laplacian of Vorticity, Vertical Gradient of Thermal Wind and Kinetic Energy we arrive at the KAT Field which is our end product for the area of high probability of CAT occurrences. Even though a higher correlation may be seen in some fields other than the KAT field, one should realize that these fields encompassed a larger than average area. In such cases one must expect a high correlation.

The high correlation is then not due to the finesse of the forecast method, but rather due to the fact that for most of the USA there was a forecast of high probability for CAT. Theoretically, it would be a good idea to divide the percent correlation (such as we computed) by the size of the area for which CAT was forecasted. We did not follow this idea quantitatively, but only qualitatively. Therefore, one finds that the percent correlation for our ultimate forecast (labeled KAT) is sometimes lower than the percent correlation for one of the three separate forecasting fields.

Table 5 is a summary for the three day period. It shows the total number of CAT occurrences by turbulence category, percent correlation by field and turbulence category, and the three day percent correlation by field.

The results were most encouraging and we feel that our end product was a substantial step in at least the right direction toward forecasting clear air turbulence. Our knowledge of the meso- and micro- structure of flow patterns in the free atmosphere, especially above the tropopause, is still rather poor. A strong need still exists for a well organized and well equipped measurement program, especially at flight levels of the future supersonic transport aircraft. Measurement programs using

methods of data collection other than aircraft should be sought in order to obtain more information on the real micro- structure of the atmosphere, without the large disturbances which a flying aircraft will create itself.

Case studies of CAT occurrences so far were limited to a comparison of turbulence location with atmospheric parameters measured as closely as possible to the time of occurrence. We might gain some additional information on the physical causes of CAT if the development and previous history of flow patterns bearing CAT were studied.

There still exists a need for sensitive, accurate and compact instrumentation, especially an accelerometer which measures and records the three components of gustiness separately and simultaneously.

In summarizing we would like to state that turbulence research in the free atmosphere has come a long way, especially when we consider the fact that measurements are most difficult to duplicate in controlled experiments. We need the free atmosphere above us to conduct our research, and this same atmosphere has an infinite choice of parameter combinations. This should provide the seed of interest to combine the efforts of physics, aerodynamics, mathematics, statistics and meteorology to seek out and find a more complete and more satisfying solution of the problem.

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# 6. APPENDIX A

## EQUATIONS

The numbers in parentheses on this and the following pages refer to the page numbers in the text where each item is discussed.

The numbers below each term in the following two equations identify the number of each term (e.g., KAT1 is the sixth term).

## THE RESEARCH PROGRAM (p. 15)

$$\underset{6}{KAT1} = \underset{1}{2^a A} - \underset{2}{2^b B} - \underset{3}{2^c C} - \underset{4}{2^d D} - \underset{5}{2^e E} \qquad \underset{9}{KAT2} = \underset{6}{KAT1} - \underset{7}{2^f F} - \underset{8}{2^g G}$$

## THE FIRST TERM $2^a A$ (p. 15)

$$a = 0 \qquad A = \nabla^2 \eta \qquad \eta_0 = f + \frac{g}{fd^2}\left[Z_1 + Z_2 + Z_3 + Z_4 - 4Z_0\right]$$

$$\nabla^2 \eta_0 = \frac{1}{d^2}\left[\eta_1 + \eta_2 + \eta_3 + \eta_4 - 4\eta_0\right] \qquad \nabla^2 \eta = 1/2\left[\nabla^2 \eta_u + \nabla^2 \eta_L\right]$$

## THE SECOND TERM $2^b B$ (p. 16)

$$b = 0 \qquad B = \left|\frac{\Delta \vec{V}_t}{\Delta P}\right|$$

$$U_t = \frac{-g}{fT}\,\frac{[T_2 - T_4]}{2d} \qquad V_t = \frac{g}{fT}\,\frac{[T_3 - T_1]}{2d} \qquad \vec{V}_{t_u} = U_{t_u} i + V_{t_u} j$$

$$\vec{V}_{t_L} = U_{t_L} i + V_{t_L} j \qquad \frac{\Delta \vec{V}_t}{\Delta P} = \frac{\vec{V}_{t_L} - \vec{V}_{t_u}}{\Delta P} = \frac{[U_{t_L} i + V_{t_L}]}{\Delta P} - \frac{[U_{t_L} i + V_{t_L} j]}{\Delta P}$$

$$\frac{\Delta\vec{V}_t}{\Delta P} = \frac{[U_{t_L} - U_{t_u}]}{\Delta P} i + \frac{[V_{t_L} - V_{t_u}]}{\Delta P} j = \frac{\Delta U_t}{\Delta P} i + \frac{\Delta V_t}{\Delta P} j$$

$$\left|\frac{\Delta V_t}{\Delta P}\right| = \left(\frac{\Delta U_t}{\Delta P}\right)^2 + \left(\frac{\Delta V_t}{\Delta P}\right)^2$$

THE THIRD TERM $2^cC$ (p. 16)

$$c = 0 \qquad C = \frac{\bar{\vec{V}}^2}{2}$$

$$U_g = \frac{-g}{f} \frac{[Z_2 - Z_4]}{2d} \qquad V_g = \frac{g}{f} \frac{[Z_3 - Z_1]}{2d}$$

$$\bar{U}_g = \frac{U_{g_u} + U_{g_L}}{2} \qquad \bar{V}_g = \frac{V_{g_u} + V_{g_L}}{2}$$

$$\bar{\vec{V}}_g = \bar{U}_g i + \bar{V}_g j \qquad \bar{\vec{V}}^2_g = (\bar{U}_g)^2 + (\bar{V}_g)^2$$

THE FOURTH TERM $2^dD$ (p. 17)

$$d = 1 \qquad D = \left|\frac{\Delta\frac{\bar{\vec{V}}^2}{2}}{\Delta P}\right|$$

$$\frac{\Delta\bar{\vec{V}}^2}{\Delta P} = \frac{\bar{\vec{V}}^2_L - \bar{\vec{V}}^2_u}{\Delta P} \qquad \left|\frac{\Delta\bar{\vec{V}}^2}{\Delta P}\right| = \sqrt{\left(\frac{\Delta\bar{\vec{V}}^2}{\Delta P}\right)^2}$$

THE FIFTH TERM $2^{e}E$ (p. 18)

$e = 1 \qquad E = \left|\nabla^2 \frac{\bar{\vec{V}}^2}{2}\right|$

$$\nabla^2 \bar{\vec{V}}_0^2 = \frac{1}{d^2}\left[\bar{\vec{V}}_1^2 + \bar{\vec{V}}_2^2 + \bar{\vec{V}}_3^2 + \bar{\vec{V}}_4^2 - 4\bar{\vec{V}}_0^2\right] \qquad \left|\nabla^2 \bar{\vec{V}}_0^2\right| = \sqrt{(\nabla^2 \bar{\vec{V}}_0^2)^2}$$

THE SIXTH TERM (p. 18)

$$KAT1 = \nabla^2 \eta - \left|\frac{\Delta \vec{V}_t}{\Delta P}\right| - \frac{\bar{\vec{V}}^2}{2} - \left|\frac{\Delta \bar{\vec{V}}^2}{\Delta P}\right| - \left|\nabla^2 \frac{\bar{\vec{V}}^2}{2}\right|$$

THE SEVENTH TERM $2^{f}F$ (p. 18)

$f = 11 \qquad F = J[T,\omega]$

$$J[T, \nabla_3 \cdot \vec{V}] = \frac{-1}{\gamma P} J[T,\omega]$$

$$J[T,\omega] = \frac{1}{4d^2}\left[(T_3 - T_1)(\omega_2 - \omega_4) - (T_2 - T_4)(\omega_3 - \omega_1)\right]$$

THE EIGHTH TERM $2^{g}G$ (p. 19)

$g = 13 \qquad G = \left|\frac{\Delta\omega}{\Delta P}\right|$

$$\frac{\Delta\omega}{\Delta P} = \frac{1}{\Delta P}\left[\omega_L - \omega_u\right] \qquad \left|\frac{\Delta\omega}{\Delta P}\right| = \frac{1}{\Delta P}\sqrt{(\omega_L - \omega_u)^2}$$

THE NINTH TERM (p. 20)

$$KAT2 = KAT1 + 2^{11}\, J[T,\omega] - 2^{13}\left|\frac{\Delta\omega}{\Delta P}\right|$$

PROG KAT PROGRAM (p. 20)

$$KAT = 2^{-1}\, \nabla^2\eta - \left|\frac{\Delta\vec{V}T}{\Delta P}\right| - \frac{\bar{\vec{V}}^2}{2}$$

# 7. APPENDIX B

## THE RESEARCH COMPUTER PROGRAM

```
F     00000  2C 0 00000                    IDENT   ETTEL MORGAN      MAT FOR CAST
                                                                     BEGIN STEERING PROGRAM
                                                                     COMPUTES 500 TO 300 MB LAYER
             50 1 00000
                  00600                    ORG     6000B
       00600 20 0 02001                    STA     TIME              PUT DATE TIME IN A REGISTER
             50 0 00000
       00601 75 4 00720          START     RTJ     READD2            READS PACKED LOWER LEVEL D FIELD INTO
                                                                     FS4
             50 0 00000
       00602 75 4 00726          +         RTJ     UNPCKD2           UNPACKS LOWER LEVEL D FIELD INTO FS1
             50 0 00000
       00603 75 4 00746          +         RTJ     READT2            READS LOWER LEVEL TEMPERATURE FIELD
                                                                     INTO FS4
             50 0 00000
       00604 75 4 00754          +         RTJ     UNPCKT2           UNPACKS LOWER LEVEL TEMPERATURE FIELD
                                                                     INTO FS3
             50 0 00000
       00605 75 4 00705          +         RTJ     READD1            READS PACKED UPPER LEVEL D FIELD INTO
                                                                     FS4
             50 0 00000
       00606 75 4 00713          +         RTJ     UNPCKD1           UNPACKS UPPER LEVEL D FIELD INTO FS0
             50 0 00000
       00607 75 4 00733          +         RTJ     READT1            READS UPPER LEVEL TEMPERATURE FIELD IN
                                                                     TO FS4
             50 0 00000
       00610 75 4 00741          +         RTJ     UNPCKT1           UNPACKS UPPER LEVEL TEMPERATURE FIELD
                                                                     INTO FS2
             50 0 00000
       00611 75 4 00761          +         RTJ     REWIND            REWINDS TO 3 CH 5/6
             50 0 00000
       00612 75 4 00765          +         RTJ     REWIND1
             50 0 00000
       00613 75 4 01447          +         RTJ     PRINT             PRINTS LOWER HEIGHT FIELD
             50 0 00000
       00614 75 4 00771          +         RTJ     SINE              GENERATES SINE FIELD STORS IN FS4
             50 0 00000
       00615 75 4 00774          +         RTJ     VORTIS1           COMPUTES VORTICITY FIELD FROM UPPER
                                                                     LEVEL D FIELD STORS IN FS5
             50 0 00000
       00616 75 4 01001          +         RTJ     VORTIS2           COMPUTES VORTICITY FIELD FROM LOWER
                                                                     LEVEL D FIELD STORS IN FS6
             50 0 00000
       00617 75 4 01006          +         RTJ     LAPLAC1           COMPUTES LAPLACIAN OF UPPER LEVEL VORT
                                                                     ICITY FIELD STORS IN FS0
             50 0 00000
```

| | | | | | |
|---|---|---|---|---|---|
| C0620 | 75 4 01214<br>50 0 00000 | + | RTJ | LAPLAC2 | COMPUTES LAPLACIAN OF LOWER LEVEL VORTICITY FIELD STOWS IN FS1 |
| C0621 | 75 4 01322<br>50 0 00000 | + | RTJ | HORIZ | COMPUTES AVERAGE VORTICITY BETWEEN UPPER AND LOWER LEVELS STOWS IN FS5 |
| 00622 | 75 4 01473<br>50 0 00000 | + | RTJ | PRINT1 | |
| 00623 | 75 4 01527<br>50 0 00000 | + | RTJ | MHAT | STOWS SCALED MAP FACTOR IN FS6 |
| 00624 | 75 4 01535<br>50 0 00000 | + | RTJ | UTHM1 | COMPUTES U COMPONENT OF THERMAL WIND AT LOWER LEVEL STOWS IN FS0 |
| 00625 | 75 4 01653<br>50 0 00000 | + | RTJ | UTHM2 | COMPUTES U COMPONENT OF THERMAL WIND AT LOWER LEVEL STOWS IN FS1 |
| 00626 | 75 4 01771<br>50 0 00000 | + | RTJ | DUTHM | COMPUTES U COMPONENT DIFFERANCE BETWEEN UPPER AND LOWER LEVELS STOWS IN FS0 |
| 00627 | 75 4 01876<br>50 0 00000 | + | RTJ | VTHM1 | COMPUTES V COMPONENT OF THERMAL WIND AT LOWER LEVEL STOWS IN FS1 |
| 00630 | 75 4 01114<br>50 0 00000 | + | RTJ | VTHM2 | COMPUTES V COMPONENT OF THERMAL WIND AT UPPER LEVEL STOWS IN FS2 |
| 00631 | 75 4 01132<br>50 0 00000 | + | RTJ | DVTHM | COMPUTES V COMPONENT DIFFERANCE BETWEEM UPPER AND LOWER LEVELS STOWS IN FS1 |
| 00632 | 75 4 01137<br>50 0 00000 | + | RTJ | DTHM | COMPUTES VERTICAL GRADIENT OF THERMAL WIND STOWS IN FS0 |
| 00633 | 75 4 01517<br>50 0 00000 | + | RTJ | PRINT2 | |
| 00634 | 75 4 01147<br>50 0 00000 | + | RTJ | KAT1 | HORIZ MINUS DTHM STOWS IN FS5 |
| 00635 | 75 4 00720<br>50 0 00000 | + | RTJ | READD2 | SEE ABOVE |
| 00636 | 75 4 00726<br>50 0 00000 | + | RTJ | UNPCKD2 | SEE ABOVE |
| 00637 | 75 4 00705<br>50 0 00000 | + | RTJ | READD1 | SEE ABOVE |
| 00640 | 75 4 00713<br>50 0 00000 | + | RTJ | UNPCKD1 | SEE ABOVE |
| 00641 | 75 4 00761<br>50 0 00000 | + | RTJ | REWIND | REWINDS TO 3 CH 5/6 |
| 00642 | 75 4 00765<br>50 0 00000 | + | RTJ | REWIND1 | |

| | | | | | |
|---|---|---|---|---|---|
| 00643 | 75 4 00771<br>50 0 00000 | + | RTJ | SINF | SEE ABOVE |
| 00644 | 75 4 01127<br>50 0 00000 | + | RTJ | MHAT | SEE ABOVE |
| 00645 | 75 4 01154<br>50 0 00000 | + | RTJ | UGEOS1 | COMPUTES U COMPONENT OF GEOSTROPHIC WIND AT UPPER LEVEL STOWS IN FS2 |
| 00646 | 75 4 01172<br>50 0 00000 | + | RTJ | UGEOS2 | COMPUTES U COMPONENT OF GEOSTROPHIC WIND AT LOWER LEVEL STOWS IN FS3 |
| 00647 | 75 4 01210<br>50 0 00000 | + | RTJ | UGEOS | COMPUTES AVERAGE U COMPONENT STOWS IN FS2 |
| 00650 | 75 4 01217<br>50 0 00000 | + | RTJ | VGEOS1 | COMPUTES V COMPONENT OF GEOSTROPHIC WIND AT UPPER LEVEL STOWS IN FS3 |
| 00651 | 75 4 01235<br>50 0 00000 | + | RTJ | VGEOS2 | COMPUTES V COMPONENT OF GEOSTROPHIC WIND AT LOWER LEVEL STOWS IN FS3 |
| 00652 | 75 4 01253<br>50 0 00000 | + | RTJ | VGEOS | COMPUTES AVERAGE V COMPONENT STOWS IN FS0 |
| 00653 | 75 4 01262<br>50 0 00000 | + | RTJ | KINETIC | COMPUTES V SQUARE STOWS IN FS0<br>COMPUTES V SQ DIFF STOWS IN FS4 |
| 00654 | 75 4 01567<br>50 0 00000 | + | RTJ | PRINT4 | |
| 00655 | 75 4 01613<br>50 0 00000 | + | RTJ | PRINT5 | |
| 00656 | 75 4 01274<br>50 0 00000 | + | RTJ | LAPKIN | COMPUTES LAPLACIAN OF KINETIC ENERGY STOWS IN FS6 |
| 00657 | 75 4 01637<br>50 0 00000 | + | RTJ | PRINT6 | |
| 00660 | 75 4 01306<br>50 0 00000 | + | RTJ | KAT2 | STOWS PREVIOUS TERMS IN FS0 |
| 00661 | 75 4 01663<br>50 0 00000 | + | RTJ | PRINT7 | |
| 00662 | 75 4 00746<br>50 0 00000 | + | RTJ | READT2 | SEE ABOVE |
| 00663 | 75 4 00754<br>50 0 00000 | + | RTJ | UNPCKT2 | SEE ABOVE |
| 00664 | 75 4 00761<br>50 0 00000 | + | RTJ | REWIND | REWINDS TU 3 CH 5/6 |
| 00665 | 75 4 01327<br>50 0 00000 | + | RTJ | READ02 | READS OMEGA FIELD INTO FS4 |
| 00666 | 75 4 01335<br>50 0 00000 | + | RTJ | UNPCK02 | UNPACKS LOWER LVL OMEGA INTO FS6 |

```
00667   75 4 00765      +       RTJ     REWIND1         REWINDS TO2 CH 5/6
        50 0 00000

00670   75 4 01342      +       RTJ     MOORE           COMPUTE, THE JACOBIAN OF TEMPERATURE AND
                                                        OMEGA STORS IN FS1
        50 0 00000

00671   75 4 01414      +       RTJ     READ01          READS OMEGA FIELD INTO FS4
        50 0 00000

00672   75 4 01322      +       RTJ     UNPCK01         UNPACKS UPPER LVL OMEGA INTO FS5
        50 0 00000

00673   75 4 00765      +       RTJ     REWIND1
        50 0 00000

00674   75 4 01355      +       RTJ     HORDVG          COMPUTE, HORIZONTAL DIVERGENCE STORS FS5
        50 0 00000

00675   75 4 01365      +       RTJ     ABSDIV          COMPUTES ABSOLUTE DIVERG STORS IN FS5
        50 0 00000

00676   75 4 01707      +       RTJ     PRINT8
        50 0 00000

00677   75 4 01543      +       RTJ     PRINT3
        50 0 00000

00700   75 4 01373      +       RTJ     KAT             COMPUTES VORTICITY DIFFERANCE PLUS
                                                        THERMAL WIND DIFFERANCE PLUS KINETIC
                                                        ENERGY DIFFERANCE PLUS THE CHANGE IN
                                                        KINETIC ENERGY PLUS KINETIC ENERGY
                                                        PLUS THE DIVERGENCE
        50 0 00000

00701   75 4 01663      +       RTJ     PRINT7
        50 0 00000

00702   75 4 01400      +       RTJ     LAYER2          COMPUTES 300 TO 200 MB LAYER
        50 0 00000

00703   75 4 01424      +       RTJ     LAYER3          COMPUTES 200 TO 100 MB LAYER
        50 0 00000

00704   76 0 00000      +       SLS                     END OF STEERING PROGRAM USES OFF LINE
                                                        PRINTING
        50 0 00000

00705   75 0 00000      READD1  SLJ     **
        50 0 00000

00706   10 0 02001      +       LDA     TIME
        14 0 01735              LDC     NAME1

00707   75 4 04231      +       RTJ     MAG
        00 0 00000              00      0,0

00710   56 0 02014      HIGHD   SNI     MAA
        50 0 01300              LNI     1300B

00711   56 0 44215              ENI     FS4
        52 0 02007              ENI     READERR

00712   75 0 00705              SLJ     READD1
        50 0 00000

00713   75 0 00000      UNPCK 1 SLJ     **
        52 6 00100              ENI     0,6
```

```
00714   75 4 00716      +       SLJ     *+2
        00 0 44215              00      FS4

00715   00 0 05015              00      FS2
        00 0 02453              00      24538

00716   75 4 04715      +       RTJ     WAB
        50 0 00007              ENI     7

00717   75 0 00713              SLJ     UNPCKD1
        50 0 00000

00720   75 0 00000      READD2  SLJ     **
        50 0 00000

00721   12 0 02001      +       LDA     TIME
        16 0 01743              LDQ     NAME2

00722   75 4 04231      +       RTJ     MAG
        00 0 00000              00      0,0

00723   50 0 02014              ENI     MAA
        50 0 01300              ENI     13008

00724   50 0 44215              ENI     FS4
        50 0 02507              ENI     READERR

00725   75 0 00720              SLJ     READD2
        50 0 00000

00726   75 0 00000      UNPCKD2 SLJ     **
        50 0 00000              ENI     0,6

00727   75 0 00731      +       SLJ     *+2
        00 0 44215              00      FS4

00730   00 0 14655              00      FS1
        00 0 02453              00      24538

00731   75 4 04715      +       RTJ     WAB
        50 0 00007              ENI     7

00732   75 0 00726              SLJ     UNPCKD2
        50 0 00000

00733   75 0 00000      READT1  SLJ     **
        50 0 00000

00734   12 0 02001      +       LDA     TIME
        16 0 01743              LDQ     NAME3

00735   75 4 04231      +       RTJ     MAG
        00 0 00000              00      0,0

00736   50 0 02014      HIGHT   ENI     MAA
        50 0 01300              ENI     13008

00737   50 0 44215              ENI     FS4
        50 0 02507              ENI     READERR

00740   75 0 00733              SLJ     READT1
        50 0 00000

00741   75 0 00000      UNPCKT1 SLJ     **
        50 0 00000              ENI     0,6

00742   75 0 00744      +       SLJ     *+2
        00 0 44215              00      FS4

00743   00 0 24515              00      FS2
        00 0 02453              00      24538
```

```
00744   75 4 04715      +       RTJ     WAB
        50 0 00007              ENI     7

00745   75 0 00741              SLJ     UNPCKT1
        50 0 00000

00746   75 0 00000      READT2  SLJ     **
        50 0 00000

00747   12 0 02001      +       LDA     TIME
        16 0 01744              LDQ     NAME4

00750   75 4 04231      +       RTJ     MAG
        00 1 00000              00      0,0

00751   50 0 02014              ENI     MAA
        50 0 01300              ENI     1300B

00752   50 0 44215              ENI     FS4
        50 0 02007              ENI     READERR

00753   75 0 00746              SLJ     READT2
        50 0 00000

00754   75 0 00000      UNPCKT2 SLJ     **
        50 6 00000              ENI     0,6

00755   75 0 00757      +       SLJ     *+2
        00 0 44215              00      FS4

00756   00 0 34355              00      FS3
        00 0 02453              00      24538

00757   75 4 04715      +       RTJ     WAB
        50 0 00007              ENI     7

00760   75 0 00754              SLJ     UNPCKT2
        50 0 00000

00761   75 0 00000      REWIND  SLJ     **
        50 0 00000

00762   75 4 02014      +       RTJ     MAA
        00 0 11306              00      11306B

00763   75 0 00761      +       SLJ     REWIND
        50 0 00000

00764   75 0 02013      +       SLJ     WINDERR
        50 0 00000

00765   75 0 00000      REWIND1 SLJ     **
        50 0 00000

00766   75 4 02014      +       RTJ     MAA
        00 0 11206              00      11206B

00767   75 0 00765      +       SLJ     REWIND1
        50 0 00000

00770   75 0 02013      +       SLJ     WINDERR
        50 0 00000

00771   75 0 00000      SINF    SLJ     **
        50 0 00000

00772   75 4 04535      +       RTJ     SAI
        50 0 44215              ENI     FS4

00773   75 0 00771      +       SLJ     SINF
        50 0 00000
```

```
00774   75 5 00000          VORTIS1  SLJ     **
        50 0 00000

00775   75 4 04611          +        RTJ     SAR
        50 0 44215                   ENI     FS4

00776   50 0 05015                   ENI     FS0
        50 0 54055                   ENI     FS5

00777   50 0 02011                   ENI     VORTER1
        50 0 04451                   ENI     SAH

01000   75 0 00774                   SLJ     VORTIS1
        50 0 00000

01001   75 0 00000          VORTIS2  SLJ     **
        50 0 00000

01002   75 4 04611          +        RTJ     SAR
        50 0 44215                   ENI     FS4

01003   50 0 14655                   ENI     FS1
        50 0 63715                   ENI     FS6

01004   50 0 02012                   ENI     VORTER2
        50 0 04451                   ENI     SAH

01005   75 0 01001                   SLJ     VORTIS2
        50 0 00000

01006   75 0 00000          LAPLAC1  SLJ     **
        50 0 00000

01007   75 4 04423          +        RTJ     SAD
        00 0 05015                   00      FS0

01010   00 0 54055                   00      FS5
        00 0 02004                   00      LAPERR1

01011   75 4 04451          +        RTJ     SAH
        50 0 04447                   ENI     SAD+24B

01012   50 0 04435                   ENI     SAD+12B
        50 0 04435                   ENI     SAD+12B

01013   75 0 01006                   SLJ     LAPLAC1
        50 0 00000

01014   75 0 00000          LAPLAC2  SLJ     **
        50 0 00000

01015   75 4 04423          +        RTJ     SAD
        00 0 14655                   00      FS1

01016   00 0 63715                   00      FS6
        00 0 02005                   00      LAPERR2

01017   75 4 04451          +        RTJ     SAH
        50 0 04447                   ENI     SAD+24B

01020   50 0 04435                   ENI     SAD+12B
        50 0 04435                   ENI     SAD+12B

01021   75 0 01014                   SLJ     LAPLAC2
        50 0 00000

01022   75 0 00000          HORIZ    SLJ     **
        50 4 00000                   ENI     0,4

01023   12 4 05015          LOOP1    LDA     FS0,4
        14 4 14655                   ADD     FS1,4
```

```
01024   20 4 54055                      STA     FS5,4
        50 0 00000

01025   54 4 07600      +               ISK     7600B,4
        75 4 01023                      SLJ     LOCP1

01026   75 0 01022                      SLJ     HORIZ
        50 0 00000

01027   75 0 00000      MHAT            SLJ     **
        50 0 00000

01030   75 4 04576      +               RTJ     SAJ
        00 0 02302                      00      HATERR

01031   50 0 44215                      ENI     FS4
        50 0 63715                      ENI     FS6

01032   75 4 04451      +               RTJ     SAH
        00 0 04577                      00      SAJ+7B

01033   50 0 04577                      ENI     SAJ+7B
        50 0 04577                      ENI     SAJ+7B

01034   75 0 01027                      SLJ     MHAT
        50 0 00000

01035   75 0 00000      UTHM1           SLJ     **
        50 0 00000

01036   75 4 04451      DIF1            RTJ     SAH
        00 0 01041                      00      OUTSID1

01037   50 0 01043      +               ENI     INSID1
        50 0 01043                      ENI     INSID1

01040   75 0 01035      +               SLJ     UTHM1
        50 0 00000

01041   10 0 00000      OUTSID1         ENA     0
        20 2 05015                      STA     FS0,2

01042   75 0 01036                      SLJ     DIF1
        50 0 00000

01043   12 2 44215      INSID1          LDA     FS4,2
        01 0 00001                      ARS     1

01044   14 0 01733                      ADD     CONST1
        20 4 01775                      STA     LOCAT1

01045   26 4 01775                      MUF     LOCAT1
        20 0 01775                      STA     LOCAT1

01046   12 3 24515                      LDA     FS2,3
        15 1 24515                      SUB     FS2,1

01047   20 0 01776                      STA     LOCAT2
        12 0 01734                      LDA     CONST2

01050   26 2 63715                      MUF     FS6,2
        26 4 01776                      MUF     LOCAT2

01051   27 0 01775                      OVF     LOCAT1
        27 2 24515                      OVF     FS2,2

01052   20 2 05015                      STA     FS0,2
        75 0 01036                      SLJ     DIF1

01053   75 0 00000      UTHM2           SLJ     **
        50 0 00000
```

```
01054   75 4 04451      DIF2    RTJ     SAH
        00 0 01157              00      OUTSID2

01055   50 0 01161      +       ENI     INSID2
        50 0 01161              ENI     INSID2

01056   75 0 01053      +       SLJ     UTHM2
        50 0 00000

01057   10 0 00000      OUTSID2 ENA     0
        20 2 14655              STA     FS1,2

01060   75 0 01054              SLJ     DIF2
        50 0 00000

01061   12 2 44215      INSID2  LDA     FS4,2
        01 0 00001              ARS     1

01062   14 0 01733              ADD     CONST1
        20 0 01775              STA     LOCAT1

01063   26 0 01775              MUF     LOCAT1
        20 0 01775              STA     LOCAT1

01064   12 3 34355              LDA     FS3,3
        15 1 34355              SUB     FS3,1

01065   20 0 01776              STA     LOCAT2
        12 0 01734              LDA     CONST2

01066   26 2 63715              MUF     FS6,2
        26 0 01776              MUF     LOCAT2

01067   27 0 01775              DVF     LOCAT1
        27 2 34355              DVF     FS3,2

01070   20 2 14655              STA     FS1,2
        75 0 01054              SLJ     DIF2

01071   75 0 00000      OUTHM   SLJ     **
        50 4 00000              ENI     0,4

01072   12 4 05015      LOOP4   LDA     FS0,4
        15 4 14655              SUB     FS1,4

01073   20 4 05015              STA     FS0,4
        50 0 00000

01074   54 4 07600      +       ISK     7600B,4
        75 0 01072              SLJ     LOOP4

01075   75 0 01071              SLJ     OUTHM
        50 0 00000

01076   75 0 00000      VTHM1   SLJ     **
        50 0 00000

01077   75 4 04451      DIF3    RTJ     SAH
        00 0 01102              00      OUTSID3

01100   50 0 01104      +       ENI     INSID3
        50 0 01104              ENI     INSID3

01101   75 0 01076      +       SLJ     VTHM1
        50 0 00000

01102   10 0 00000      OUTSID3 ENA     0
        20 2 14655              STA     FS1,2

01103   75 0 01077              SLJ     DIF3
        50 0 00000
```

```
01104   12 2 44215      INSID3  LDA     FS4,2
        01 0 00001              ARS     1

01105   14 0 01733              ADD     CONST1
        20 0 01775              STA     LOCAT1

01106   26 0 01775              MUF     LOCAT1
        20 0 01775              STA     LOCAT1

01107   12 6 24516              LDA     FS2+1,2
        15 2 24514              SUB     FS2-1,2

01110   20 0 01776              STA     LOCAT2
        12 0 01734              LDA     CONST2

01111   26 4 63715              MUF     FS6,2
        26 0 01776              MUF     LOCAT2

01112   27 0 01775              DVF     LOCAT1
        27 2 24515              DVF     FS2,2

01113   20 2 14655              STA     FS1,2
        75 0 01077              SLJ     DIF3

01114   75 0 00000      VTHM2   SLJ     **
        50 0 00000

01115   75 4 04451      DIF4    RTJ     SAH
        00 0 01120              +0      OUTSID4

01116   50 0 01122      +       ENI     INSID4
        50 0 01122              ENI     INSID4

01117   75 0 01114      +       SLJ     VTHM2
        50 0 00000

01120   10 0 00000      OUTSID4 LNA     0
        20 2 24515              STA     FS2,2

01121   75 0 01115              SLJ     DIF4
        50 0 00000

01122   12 2 44215      INSID4  LDA     FS4,2
        01 0 00001              ARS     1

01123   14 0 01733              ADD     CONST1
        20 0 01775              STA     LOCAT1

01124   26 0 01775              MUF     LOCAT1
        20 0 01775              STA     LOCAT1

01125   12 2 34356              LDA     FS3+1,2
        15 2 34354              SUB     FS3-1,2

01126   20 0 01776              STA     LOCAT2
        12 0 01734              LDA     CONST2

01127   26 2 63715              MUF     FS6,2
        26 0 01776              MUF     LOCAT2

01130   27 0 01775              DVF     LOCAT1
        27 2 34355              DVF     FS3,2

01131   20 2 24515              STA     FS2,2
        75 0 01115              SLJ     DIF4

01132   75 4 00000      DVTHM   SLJ     **
        50 4 00000              ENI     0,4

01133   12 4 24515      LOOP7   LDA     FS2,4
        15 4 14655              SUB     FS1,4
```

```
01134   20 4 14655          STA   FS1,4
        50 0 00000

01135   54 4 07600    +     ISK   7600B,4
        75 0 01133          SLJ   LOOP7

01136   75 0 01132          SLJ   DVTHM
        50 0 00000

01137   75 0 00000    DTHM  SLJ   **
        50 4 00000          ENI   0,4

01140   12 4 05015    LOOP8 LDA   FS0,4
        26 4 05015          MUF   FS0,4

01141   20 4 05015          STA   FS0,4
        12 4 14655          LDA   FS1,4

01142   26 4 14655          MUF   FS1,4
        14 4 05015          ADD   FS0,4

01143   75 4 04666    +     RTJ   VAB
        00 0 02017          00    SQERR

01144   20 4 05015    +     STA   FS0,4
        50 0 00000

01145   54 4 07600    +     ISK   7600B,4
        75 0 01140          SLJ   LOOP8

01146   75 0 01137          SLJ   DTHM
        50 0 00000

01147   75 0 00000    KAT1  SLJ   **
        50 4 00000          ENI   0,4

01150   12 4 54055    LOOP9 LDA   FS5,4
        15 4 05015          SUB   FS0,4

01151   20 4 54055          STA   FS5,4
        50 0 00000

01152   54 4 07600    +     ISK   7600B,4
        75 0 01150          SLJ   LOOP9

01153   75 0 01147          SLJ   KAT1
        50 0 00000

01154   75 0 00000    UGEOS1 SLJ  **
        50 0 00000

01155   75 4 04451    DIF5  RTJ   SAH
        00 0 01160          00    OUTSID5

01156   50 0 01162    +     ENI   INSID5
        50 0 01162          ENI   INSID5

01157   75 0 01154    +     SLJ   UGEOS1
        50 0 00000

01160   10 0 00000    OUTSID5 ENA 0
        20 2 24515          STA   FS2,2

01161   75 0 01155          SLJ   DIF5
        50 0 00000

01162   12 2 44215    INSID5 LDA  FS4,2
        01 0 00001          ARS   1

01163   14 0 01733          ADD   CONST1
        20 0 01775          STA   LOCAT1
```

```
01164   26 0 01775          MUF   LOCAT1
        20 0 01775          STA   LOCAT1

01165   12 3 05015          LDA   FS0,3
        15 1 05015          SUB   FS0,1

01166   20 0 01776          STA   LOCAT2
        12 0 01734          LDA   CONST2

01167   26 2 63715          MUF   FS6,2
        26 0 01776          MUF   LOCAT2

01170   27 0 01775          DVF   LOCAT1
        20 2 24515          STA   FS2,2

01171   75 0 01155          SLJ   DIF5
        50 0 00000

01172   75 0 00000  UGEOS2   SLJ   **
        50 0 00000

01173   75 4 04451  DIF6    RTJ   SAH
        00 0 01176          DD    OUTSID6

01174   50 0 01200  +       ENI   INSID6
        50 0 01200          ENI   INSID6

01175   75 0 01172  +       SLJ   UGEOS2
        50 0 00000

01176   10 0 00000  OUTSID6  ENA   0
        20 2 34355          STA   FS3,2

01177   75 0 01173          SLJ   DIF6
        50 0 00000

01200   12 2 44215  INSID6  LDA   FS4,2
        01 0 00001          ARS   1

01201   14 0 01733          ADD   CONST1
        20 0 01775          STA   LOCAT1

01202   26 0 01775          MUF   LOCAT1
        20 0 01775          STA   LOCAT1

01203   12 3 14655          LDA   FS1,3
        15 1 14655          SUB   FS1,1

01204   20 0 01776          STA   LOCAT2
        12 0 01734          LDA   CONST2

01205   26 2 63715          MUF   FS6,2
        26 0 01776          MUF   LOCAT2

01206   27 0 01775          DVF   LOCAT1
        20 2 34355          STA   FS3,2

01207   75 0 01173          SLJ   DIF6
        50 0 00000

01210   75 0 00000  UGEOS    SLJ   **
        50 4 00000          ENI   0,4

01211   12 4 24515  LOOP10  LDA   FS2,4
        05 0 00003          ALS   3

01212   20 0 01775          STA   LOCAT1
        12 4 34355          LDA   FS3,4

01213   05 0 00003          ALS   3
        14 0 01775          ADD   LOCAT1
```

```
01214   20 4 24515          STA   FS2,4
        50 0 00000

01215   54 4 07600    +     ISK   7600B,4
        75 0 01211          SLJ   LOOP10

01216   75 0 01210          SLJ   UGEOS
        50 0 00000

01217   75 0 00000    VGEOS1  SLJ   **
        50 0 00000

01220   75 4 04451    DIF7    RTJ   SAH
        00 0 01223          00    OUTSID7

01221   50 0 01225    +     ENI   INSID7
        50 0 01225          ENI   INSID7

01222   75 0 01217    +     SLJ   VGEOS1
        50 0 00000

01223   10 0 00000    OUTSID7 ENA   0
        20 2 34355          STA   FS3,2

01224   75 0 01220          SLJ   DIF7
        50 0 00000

01225   12 2 44215    INSID7  LDA   FS4,2
        01 0 00001          ARS   1

01226   14 0 01733          ADD   CONST1
        20 0 01775          STA   LOCAT1

01227   26 0 01775          MUF   LOCAT1
        20 0 01775          STA   LOCAT1

01230   12 2 05016          LDA   FS0+1,2
        15 2 05014          SUB   FS0-1,2

01231   20 0 01776          STA   LOCAT2
        12 0 01734          LDA   CONST2

01232   26 2 63715          MUF   FS6,2
        26 0 01776          MUF   LOCAT2

01233   27 0 01775          DVF   LOCAT1
        20 2 34355          STA   FS3,2

01234   75 0 01220          SLJ   DIF7
        50 0 00000

01235   75 0 00000    VGEOS2  SLJ   **
        50 0 00000

01236   75 4 04451    DIF8    RTJ   SAH
        00 0 01241          00    OUTSID8

01237   50 0 01243    +     ENI   INSID8
        50 0 01243          ENI   INSID8

01240   75 0 01235    +     SLJ   VGEOS2
        50 0 00000

01241   10 0 00000    OUTSID8 ENA   0
        20 2 05015          STA   FS0,2

01242   75 0 01236          SLJ   DIF8
        50 0 00000

01243   12 2 44215    INSID8  LDA   FS4,2
        01 0 00001          ARS   1
```

```
01244   14 0 01733          ADD   CONST1
        20 0 01775          STA   LOCAT1

01245   26 0 01775          MUF   LOCAT1
        20 0 01775          STA   LOCAT1

01246   12 2 14556          LDA   FS1+1,2
        15 2 14554          SUB   FS1-1,2

01247   20 0 01776          STA   LOCAT2
        12 0 01734          LDA   CONST2

01250   26 2 63715          MUF   FS6,2
        26 0 01776          MUF   LOCAT2

01251   27 0 01775          DVF   LOCAT1
        20 2 05015          STA   FS0,2

01252   75 0 01236          SLJ   DIF8
        50 0 00000

01253   75 0 00000  VGEOS    SLJ   **
        50 4 00000          ENI   0,4

01254   12 4 34355  LOOP11   LDA   FS3,4
        35 0 00003          ALS   3

01255   20 0 01775          STA   LOCAT1
        12 4 05015          LDA   FS0,4

01256   05 0 00003          ALS   3
        14 0 01775          ADD   LOCAT1

01257   20 4 05015          STA   FS0,4
        50 0 00000

01260   54 4 07600  +        ISK   7600B,4
        75 0 01254          SLJ   LOOP11

01261   75 0 01253          SLJ   VGEOS
        50 0 00000

01262   75 0 00000  KINETIC  SLJ   **
        50 4 00000          ENI   0,4

01263   12 4 24515  LOOP12   LDA   FS2,4
        26 4 24515          MUF   FS2,4

01264   20 0 01775          STA   LOCAT1
        12 4 05015          LDA   FS0,4

01265   26 4 05015          MUF   FS0,4
        20 0 01776          STA   LOCAT2

01266   14 0 01775          ADD   LOCAT1
        01 0 00001          ARS   1

01267   20 4 05015          STA   FS0,4
        12 0 01775          LDA   LOCAT1

01270   15 0 01776          SUB   LOCAT2
        20 4 44215          STA   FS4,4

01271   26 4 44215          MUF   FS4,4
        20 4 44215          STA   FS4,4

01272   54 4 07600  +        ISK   7600B,4
        75 0 01263          SLJ   LOOP12

01273   75 0 01262          SLJ   KINETIC
        50 0 00000
```

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01274   75 0 00000      LAPKIN  SLJ     **
        50 0 00000

01275   75 4 04423      +       RTJ     SAD
        00 0 63715              00      FS6

01276   00 0 05015              00      FS0
        00 0 02006              00      LAPERR3

01277   75 4 04451      +       RTJ     SAH
        50 0 04447              ENI     SAD+24B

01300   50 0 04435              ENI     SAD+12B
        50 0 04435              ENI     SAD+12B

01301   50 4 00000              ENI     0,4
        50 0 00000

01302   12 4 63715      ABS     LDA     FS6,4
        26 4 63715              MUF     FS6,4

01303   20 4 63715              STA     FS6,4
        50 0 00000

01304   54 4 07600      +       ISK     7600B,4
        75 0 01302              SLJ     ABS

01305   75 0 01274              SLJ     LAPKIN
        50 0 00000

01306   75 0 00000      KAT2    SLJ     **
        50 4 00000              ENI     0,4

01307   12 4 54055      LOOP13  LDA     FS5,4
        15 4 05015              SUB     FS0,4

01310   15 4 63715              SUB     FS6,4
        15 4 44215              SUB     FS4,4

01311   20 4 05015              STA     FS0,4
        50 0 00000

01312   54 4 07600      +       ISK     7600B,4
        75 0 01307              SLJ     LOOP13

01313   75 0 01306              SLJ     KAT2
        50 0 00000

01314   75 0 00000      READ01  SLJ     **
        50 0 00000

01315   12 0 02001      +       LDA     TIME
        16 0 01751              LDQ     NAME5

01316   75 4 04231      +       RTJ     MAG
        00 0 00000              00      0,0

01317   50 0 02014              ENI     MAA
        50 0 01200              ENI     1200B

01320   50 0 44215              ENI     FS4
        50 0 02007              ENI     READERR

01321   75 0 01314              SLJ     READ01
        50 0 00000

01322   75 0 00000      UNPCK01 SLJ     **
        50 6 00000              ENI     0,6

01323   75 0 01325      +       SLJ     *+2
        00 0 44215              00      FS4
```

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01324   00 0 54055          00    FS5
        00 0 02453          00    2453B

01325   75 4 04715    +     RTJ   WAB
        50 0 00007          ENI   7

01326   75 0 01322          SLJ   UNPCK01
        50 0 00000

01327   75 0 00000  READ02  SLJ   **
        50 0 00000

01330   12 0 02001    +     LDA   TIME
        16 0 01754          LDQ   NAME6

01331   75 4 04231    +     RTJ   MAG
        00 0 00000          00    0,0

01332   50 0 02014          ENI   MAA
        50 0 01200          ENI   1200B

01333   50 0 44215          ENI   FS4
        50 0 02007          ENI   READERR

01334   75 0 01327          SLJ   READ02
        50 0 00000

01335   75 0 00000  UNPCK02 SLJ   **
        50 6 00000          ENI   0,6

01336   75 0 01340    +     SLJ   *+2
        00 0 44215          00    FS4

01337   00 0 63715          00    FS6
        00 0 02453          00    2453B

01340   75 4 04715    +     RTJ   WAB
        50 0 00007          ENI   7

01341   75 0 01335          SLJ   UNPCK02
        50 0 00000

01342   75 0 00000  MOORE   SLJ   **
        50 0 00000

01343   75 4 04371    +     RTJ   SAB
        00 0 14655          00    FS1

01344   00 0 34355          00    FS3
        00 0 63715          00    FS6

01345   00 0 00000    +     00    0
        00 0 02003          00    JACERR

01346   75 4 04451    +     RTJ   SAH
        50 0 04420          ENI   SAB+27B

01347   50 0 04406    +     ENI   SAB+15B
        50 0 04406          ENI   SAB+15B

01350   50 4 00000          ENI   0,4
        50 0 00000

01351   12 4 14655  SHIFT   LDA   FS1,4
        05 0 00013          ALS   11

01352   20 4 14655          STA   FS1,4
        50 0 00000

01353   54 4 07600    +     ISK   7600B,4
        75 0 01351          SLJ   SHIFT
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01354   75 0 01342          SLJ   MOORE
        50 0 00100

01355   75 0 00000  HORDVG   SLJ   **
        50 4 00000          ENI   0,4

01356   12 4 54055  LOOP15  LDA   FS5,4
        01 0 00001          ARS   1

01357   20 0 01775          STA   LOCAT1
        12 4 63715          LDA   FS6,4

01360   01 0 00001          ARS   1
        20 0 01776          STA   LOCAT2

01361   12 0 01775          LDA   LOCAT1
        15 0 01776          SUB   LOCAT2

01362   20 4 54055          STA   FS5,4
        50 0 00000

01363   54 4 07600  +       ISK   7600B,4
        75 0 01356          SLJ   LOOP15

01364   75 0 01355          SLJ   HORDVG
        50 0 00000

01365   75 0 00000  ABSDIV  SLJ   **
        50 4 00000          ENI   0,4

01366   12 4 54055  LOOP17  LDA   FS5,4
        26 4 54055          MUF   FS5,4

01367   05 0 00016          ALS   14
        50 0 00000

01370   20 4 54055  +       STA   FS5,4
        50 0 00000

01371   54 4 07600  +       ISK   7600B,4
        75 0 01366          SLJ   LOOP17

01372   75 0 01365          SLJ   ABSDIV
        50 0 00000

01373   75 0 00000  KAT     SLJ   **
        50 4 00000          ENI   0,4

01374   12 4 05015  LOOP16  LDA   FS0,4
        15 4 54055          SUB   FS5,4

01375   15 4 14655          SUB   FS1,4
        20 4 05015          STA   FS0,4

01376   54 4 07600  +       ISK   7600B,4
        75 0 01374          SLJ   LOOP16

01377   75 0 01373          SLJ   KAT
        50 0 00000

01400   75 0 00000  LAYER2  SLJ   **
        12 0 01757          LDA   COUNT

01401   05 0 00001          ALS   1
        20 0 01757          STA   COUNT

01402   22 3 01400          AJPM  LAYER2
        12 0 01736          LDA   NAME1A

01403   20 0 01735          STA   NAME1
        12 0 01741          LDA   NAME2A
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01404   20 0 01740          STA   NAME2
        12 0 01744          LDA   NAME3A

01405   20 0 01743          STA   NAME3
        12 0 01747          LDA   NAME4A

01406   20 0 01746          STA   NAME4
        12 0 01755          LDA   NAME6A

01407   20 0 01754          STA   NAME6
        12 0 01761          LDA   LEVEL2

01410   20 0 01471          STA   TITLE+3
        20 0 01515          STA   TITLE1+3

01411   20 0 01541          STA   TITLE2+3
        20 0 01565          STA   TITLE3+3

01412   20 0 01611          STA   TITLE4+3
        20 0 01635          STA   TITLE5+3

01413   20 0 01661          STA   TITLE6+3
        20 0 01705          STA   TITLE7+3

01414   20 0 01731          STA   TITLE8+3
        12 0 01763          LDA   A2

01415   20 0 01461          STA   A1
        12 0 01765          LDA   B2

01416   20 0 01462          STA   B1
        12 0 01767          LDA   C2

01417   20 0 01464          STA   C1
        12 0 01771          LDA   D2

01420   20 0 01463          STA   D1
        12 0 01773          LDA   E2

01421   61 0 01460          SAL   E1
        12 0 01777          LDA   TAPUNIT

01422   61 0 00710          SAL   HIGHD
        61 0 00736          SAL   HIGHT

01423   75 0 00601          SLJ   START
        50 0 00000

01424   75 0 00000  LAYER3   SLJ   **
        12 0 01760          LDA   COUNT1

01425   05 0 00001          ALS   1
        20 0 01760          STA   COUNT1

01426   22 3 01424          AJPM  LAYER3
        12 0 01737          LDA   NAME1B

01427   20 0 01735          STA   NAME1
        12 0 01742          LDA   NAME2B

01430   20 0 01740          STA   NAME2
        12 0 01745          LDA   NAME3B

01431   20 0 01743          STA   NAME3
        12 0 01750          LDA   NAME4B

01432   20 0 01746          STA   NAME4
        12 0 01753          LDA   NAME5B

01433   20 0 01751          STA   NAME5
        12 0 01756          LDA   NAME6B
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01434   20 0 01754          STA   NAME6
        12 0 01762          LDA   LEVEL3

01435   20 0 01471          STA   TITLE+3
        20 0 01515          STA   TITLE1+3

01436   20 0 01541          STA   TITLE2+3
        20 0 01565          STA   TITLE3+3

01437   20 0 01611          STA   TITLE4+3
        20 0 01635          STA   TITLE5+3

01440   20 0 01661          STA   TITLE6+3
        20 0 01705          STA   TITLE7+3

01441   20 0 01731          STA   TITLE8+3
        12 0 01764          LDA   A3

01442   20 0 01461          STA   A1
        12 0 01766          LDA   B3

01443   20 0 01462          STA   B1
        12 0 01770          LDA   C3

01444   20 0 01464          STA   C1
        12 0 01772          LDA   D3

01445   20 0 01463          STA   D1
        12 0 01774          LDA   E3

01446   61 0 01460          SAL   E1
        75 0 00601          SLJ   START

01447   75 0 00000  PRINT   SLJ   **
        10 0 00012          FNA   10

01450   20 0 00017          STA   17B
        50 0 00000

01451   75 0 01455  +       SLJ   *+4
        00 0 00000          00    0

01452   00 0 14655          00    FS1
        00 0 63715          00    FS6

01453   00 0 00047          00    39
        00 0 00035          00    29

01454   00 0 00022          00    18
        00 0 00010          00    8

01455   75 4 04745  +       RTJ   WAE
        00 0 00000          00    0

01456   75 4 02524  +       RTJ   MAC
        00 0 63715          00    FS6,0

01457   75 0 01447  +       SLJ   PRINT
        77 7 63715          77    FS6,7

01460   10 0 02000  E1      10    TAU
        00 0 00004          00    4

01461   13 1 11710  A1      OCT   1311171047640243
        47 6 40243

01462   02 4 76132  B1      OCT   0247613261070664
        61 0 70664

01463   00 1 42600  D1      OCT   0014260000000000
        00 0 00000
```

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01464   01 3 56300      C1      OCT     013567000000000000
        00 0 00000

01465   00 0 00026              OCT     22
        00 0 00026              OCT     22

01466   20 4 34626      TITLE   BCD     4, LOWER LEVEL Z FIELD    LAYER 1
        65 5 12043

01467   65 2 56543      TITLE   BCD     4, LOWER LEVEL Z FIELD    LAYER 1
        20 3 12066

01470   71 6 54364      TITLE   BCD     4, LOWER LEVEL Z FIELD    LAYER 1
        20 2 02020

01471   43 6 13065      TITLE   BCD     4, LOWER LEVEL Z FIELD    LAYER 1
        51 2 00120

01472   75 0 01447              SLJ     PRINT
        55 0 00000

01473   75 0 00000      PRINT1  SLJ     **
        10 0 00012              ENA     10

01474   20 0 00017              STA     17B
        00 0 00000

01475   75 0 01501      +       SLJ     **+4
        00 0 00000              0       0

01476   00 0 54355              00      FS5
        00 0 63715              00      FS6

01477   00 0 00047              00      39
        00 0 00035              00      29

01500   00 0 00022              00      18
        00 0 00010              00      8

01501   75 4 04745      +       RTJ     WAE
        00 0 00000              00      0

01502   75 4 02524      +       RTJ     MAC
        00 0 63715              00      FS6,0

01503   75 0 01473              SLJ     PRINT1
        77 7 63715              77      FS6,7

01504   10 0 02000              10      TAC
        00 0 00001              00      1

01505   00 0 00000              OCT     0
        00 0 00000

01506   20 0 00000              DEC     50-1B47
        00 0 00000

01507   00 0 00000              OCT     0
        00 0 00000

01510   63 1 46314              DEC     1D-1B47
        63 1 46314

01511   00 0 00027              00      23
        00 0 00026              00      22

01512   24 4 36147      TITLE1  BCD     4, LAPLACIAN OF VORTICITY LAYER 1
        43 5 16371

01513   41 4 52446      TITLE1  BCD     4, LAPLACIAN OF VORTICITY LAYER 1
        66 2 02546
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01514   51 2 37163      TITLE1  BCD     4, LAPLACIAN OF VORTICITY LAYER 1
        71 2 33020

01515   43 6 13065      TITLE1  BCD     4, LAPLACIAN OF VORTICITY LAYER 1
        51 2 00120

01516   75 0 01473              SLJ     PRINT1
        50 0 00000

01517   75 0 00000      PRINT2  SLJ     **
        10 0 00012              ENA     10

01520   20 0 00017              STA     17B
        50 0 00000

01521   75 0 01525      *       SLJ     *+4
        00 0 00000              00      0

01522   00 0 05015              00      FS0
        00 0 63715              00      FS6

01522   00 0 05015              00      FS0

01523   00 0 00047              00      39
        00 0 00035              00      29

01524   00 0 00022              00      18
        00 0 00010              00      8

01525   75 4 04745      SKIP    RTJ     WAE
        00 0 00000              00      0

01526   75 4 02524      *       RTJ     MAC
        00 0 63715              00      FS6,0

01527   75 0 01517              SLJ     PRINT2
        77 7 63715              77      FS6,7

01530   10 0 02000              10      TAU
        00 0 00001              00      1

01531   00 0 00000              OCT     0
        00 0 00000

01532   20 0 00000              DEC     5D-1B47
        00 0 00000

01533   00 0 00000              OCT     0
        00 0 00000

01534   00 6 31463              DEC     25D-3B47
        14 6 31463

01535   00 0 00026              00      22
        00 0 00026              00      22

01536   20 2 56551      TITLE2  BCD     4, VERT GRAD OF VT          LAYER 1
        23 2 06751

01537   61 6 42046      TITLE2  BCD     4, VERT GRAD OF VT          LAYER 1
        66 2 02523

01540   20 2 02020      TITLE2  BCD     4, VERT GRAD OF VT          LAYER 1
        20 2 02020

01541   43 6 13065      TITLE2  BCD     4, VERT GRAD OF VT          LAYER 1
        51 2 00120

01542   75 0 01517              SLJ     PRINT2
        50 0 00000

01543   75 0 00000      PRINT3  SLJ     **
        10 0 00012              ENA     10
```

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01544   20 1 00017                      STA     17B
        00 0 00000

01545   75 0 01551              +       SLJ     *+4
        00 1 00000                      0

01546   00 1 54455                      FSS
        00 1 63715                      FS6

01547   00 0 00047                      39
        00 0 00035                      29

01550   00 0 00022                      18
        00 0 00010                      8

01551   75 4 04745              +       RTJ     WAL
        00 0 00000                      0

01552   75 4 12524              +       RTJ     MAC
        00 0 63715                      FS6,0

01553   75 0 01543                      SLJ     PRINT3
        77 7 63715                      FS6,7

01554   10 1 00001                      10      TAU
        00 1 00001                      1

01555   00 0 00000                      CCT     0
        00 0 00000

01556   20 0 00000                      DEC     50-1847
        00 0 00050

01557   00 0 00000                      OCT     0
        00 0 00000

01560   03 1 46314                      DEC     10-1847
        03 1 46314

01561   00 0 00026                      22
        00 0 00026                      22

01562   20 6 12565              TITLE3  BCD     4, AVERAGE DIVERGENCE     LAYER 1
        51 6 16765

01563   20 6 47125              TITLE3  BCD     4, AVERAGE DIVERGENCE     LAYER 1
        65 5 16765

01564   45 6 36520              TITLE3  BCD     4, AVERAGE DIVERGENCE     LAYER 1
        20 2 02021

01565   43 6 13065              TITLE3  BCD     4, AVERAGE DIVERGENCE     LAYER 1
        51 2 00120

01566   75 0 01543                      SLJ     PRINT3
        50 0 00000

01567   75 0 00000              PRINT4  SLJ     **
        10 0 00012                      ENA     10

01570   20 0 00 17                      STA     17B
        50 0 00000

01571   75 1 01575              +       SLJ     *+4
        00 1 00000                      0

01572   00 3 05415                      FSS
        00 3 63715                      FS6

01573   00 0 00047                      39
        00 1 00035                      29
```

```
01574   00 0 00022          00   18
        00 0 00010          00   8

01575   75 4 04745    +     RTJ  WAE
        00 0 00000          00   0

01576   75 4 02524    +     RTJ  MAC
        00 0 63715          00   FS6,0

01577   75 0 01567          SLJ  PRINT4
        77 7 63715          77   FS6,7

01600   10 0 02000          10   TAU
        00 0 00001          00   1

01601   00 0 00000          OCT  0
        00 0 00000

01602   20 0 00000          DEC  50-1847
        00 0 00000

01603   00 0 00000          OCT  0
        00 0 00000

01604   03 1 46314          DEC  10-1847
        63 1 46314

01605   00 0 00026          00   22
        00 0 00026          00   22

01606   20 4 27145  TITLE4  BCD  4, KINETIC ENERGY      LAYER 1
        65 2 37163

01607   20 6 54565  TITLE4  BCD  4, KINETIC ENERGY      LAYER 1
        51 6 73020

01610   20 2 02020  TITLE4  BCD  4, KINETIC ENERGY      LAYER 1
        20 2 02020

01611   43 6 13065  TITLE4  BCD  4, KINETIC ENERGY      LAYER 1
        51 2 00120

01612   75 0 01567          SLJ  PRINT4
        50 0 00000

01613   75 0 00000  PRINT5  SLJ  **
        10 0 00012          ENA  10

01614   20 0 00017          STA  17B
        50 0 00000

01615   75 0 01621    +     SLJ  *+4
        00 0 00000          00   0

01616   00 0 44215          00   FS4
        00 0 63715          00   FS6

01617   00 0 00047          00   39
        00 0 00035          00   29

01620   00 0 00022          00   18
        00 0 00010          00   8

01621   75 4 04745    +     RTJ  WAE
        00 0 00000          00   0

01622   75 4 02524    +     RTJ  MAC
        00 0 63715          00   FS6,0

01623   75 0 01613          SLJ  PRINT5
        77 7 63715          77   FS6,7
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01624   10 3 02000          10      TAU
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01625   00 0 00000          OCT     0
        00 0 00000

01626   20 0 00000          DEC     5D-1B47
        00 0 00000

01627   00 0 00000          OCT     0
        00 0 00000

01630   03 1 46314          DEC     1D-1B47
        63 1 46314

01631   00 0 00026          00      22
        00 0 00026          00      22

01632   20 4 27145  TITLE1  BCD     4, KINT ENERGY DIFF     LAYER 1
        23 2 06545

01633   65 5 16730  TITLE5  BCD     4, KINT ENERGY DIFF     LAYER 1
        20 6 47166

01634   66 2 02020  TITLE6  BCD     4, KINT ENERGY DIFF     LAYER 1
        20   02020

01635   43 6 13065  TITLE7  BCD     4, KINT ENERGY DIFF     LAYER 1
        51 2 00120

01636   75 0 01613          SLJ     PRINT5
        50 0 00000

01637   75 0 00000  PRINT6  SLJ     **
        10 0 00012          ENA     10

01640   20 0 00017          STA     17B
        50 0 00000

01641   75 0 01645  +       SLJ     *+4
        00 0 00000          00      0

01642   00 0 63715          00      FS6
        00 0 14655          00      FS1

01643   00 0 00047          00      39
        00 0 00035          00      29

01644   00 0 00022          00      18
        00 0 00010          00      8

01645   75 4 04745  +       RTJ     WAE
        00 0 00000          00      0

01646   75 4 02524  +       RTJ     MAC
        00 0 14655          00      FS1,0

01647   75 0 01637          SLJ     PRINT6
        77 7 14655          77      FS1,7

01650   10 3 02000          10      TAU
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01651   00 0 00000          OCT     0
        00 0 00000

01652   20 0 00000          DEC     5D-1B47
        00 0 00000

01653   00 0 00000          OCT     0
        00 0 00000
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01654   xx x 31463          DEC     xxxx-3847
        14 5 31463

01655   xx x 00026          DEC     22
        00 0 00026          DEC     22

01656   20 6 37045  TITLE6   BCD     4, CHNG IN KINETIC ENERGY LAYER 1
        57 2 07145

01657   20 4 27145  TITLE6   BCD     4, CHNG IN KINETIC ENERGY LAYER 1
        65 2 37163

01660   20 6 54565  TITLE6   BCD     4, CHNG IN KINETIC ENERGY LAYER 1
        51 6 73120

01661   43 6 13065  TITLE6   BCD     4, CHNG IN KINETIC ENERGY LAYER 1
        51 2 00120

01662   75 0 01637          SLJ     PRINT6
        50 0 00000

01663   75 0 00000  PRINT7   SLJ     **
        10 0 00012          ENA     10

01664   20 0 00017          STA     178
        50 0 00000

01665   75 0 01671  +        SLJ     *+4
        00 0 00000          00      0

01666   00 0 05015          00      FS0
        00 0 63715          00      FS6

01667   00 0 00047          00      39
        00 0 00035          00      29

01670   00 0 00022          00      18
        00 0 00010          00      8

01671   75 4 04745  +        RTJ     WAE
        00 0 00000          00      0

01672   75 4 02524  +        RTJ     MAC
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01673   75 0 01663          SLJ     PRINT7
        77 7 63715          77      FS6,7

01674   10 0 02000          10      TAU
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01675   00 0 00000          OCT     0
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01700   10 0 00000          DEC     25D-2847
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01701   00 0 00026          00      22
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01702   20 4 75146  TITLE7   BCD     4, PROG KAT FIELD          LAYER 1
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01703   23 2 06671  TITLE7   BCD     4, PROG KAT FIELD          LAYER 1
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01704   20 2 02020          TITLE7   BCD     4, PROG KAT FIELD          LAYER 1
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01705   43 6 13065          TITLE7   BCD     4, PROG KAT FIELD          LAYER 1
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01706   75 0 01663                   SLJ     PRINT7
        50 0 00000

01707   75 0 00000          PRINT8   SLJ     **
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01710   20 0 00017                   STA     17B
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01711   75 0 01715          *        SLJ     *+4
        00 0 00000                   00      0

01712   00 0 14555                   00      FS1
        00 0 63715                   00      FS6

01713   00 0 00007                   00      39
        00 0 00035                   00      29

01714   00 0 00022                   00      18
        00 0 00010                   00      8

01715   75 4 04745          *        RTJ     WAF
        00 0 00000                   00      0

01716   75 4 02524          *        RTJ     MAC
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01717   75 0 01707                   SLJ     PRINT8
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01722   20 0 00000                   DEC     50-1847
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01723   00 0 00000                   OCT     0
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01724   03 1 46314                   DEC     10-1847
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        00 0 00026                   00      22

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        65 6 32046

01727   66 2 04644          TITLE8   BCD     4, ADVEC OF OMEGA BY TEMP LAYER 1
        65 6 76120

01730   62 3 02023          TITLE8   BCD     4, ADVEC OF OMEGA BY TEMP LAYER 1
        65 4 44720

01731   43 6 13065          TITLE8   BCD     4, ADVEC OF OMEGA BY TEMP LAYER 1
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01733   20 2 00000          CONST1   DEC     50-1847
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01750   23 2 02002      NAME4B  OCT     2320200212122020
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        03 1 21220

01752   46 4 46720      NAME5A  OCT     4644672002121220
        02 1 21220

01753   46 4 46720      NAME5B  OCT     4644672001121220
        01 1 21220

01754   46 4 46720      NAME6   OCT     4644672005121220
        05 1 21220

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01756   46 4 46720      NAME6B  OCT     4644672002121220
        02 1 21220

01757   17 7 77777      COUNT   OCT     1777777777777777
        77 7 77777

01760   17 7 77777      COUNT1  OCT     1777777777777777
        77 7 77777

01761   43 6 13065      LEVEL2  OCT     4361306551200220
        51 2 00220

01762   43 6 13065      LEVEL3  OCT     4361306551200320
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        15 0 14743
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01766   01 0 30675      B3      OCT   0103067572026573
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01767   02 7 34000      C2      OCT   0273400000000000
        00 0 00000

01770   02 7 34000      C3      OCT   0273400000000000
        00 0 00000

01771   77 0 12577      D2      OCT   7701257777777777
        77 7 77777

01772   77 3 02377      D3      OCT   7730237777777777
        77 7 77777

01773   00 0 00000      E2      OCT   2
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01774   00 0 00000      E3      OCT   2
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01775         01776     LOCAT1  BSS   1

01776         01777     LOCAT2  BSS   1

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02000   00 0 00000      TAU     DEC   24
        00 0 00030

02001   12 1 21205      TIME    OCT   1212120512010605
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02002   76 0 01027      HATERR  SLS   MHAT
        50 0 00000

02003   76 0 01342      JACERR  SLS   MOORE
        50 0 00000

02004   76 0 01006      LAPERR1 SLS   LAPLAC1
        50 0 00000

02005   76 0 01014      LAPERR2 SLS   LAPLAC2
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02006   76 0 01274      LAPERR3 SLS   LAPKIN
        50 0 00000

02007   76 0 00705      READERR SLS   READD1
        50 0 00000

02010   76 0 01137      SQERR   SLS   DTHM
        50 0 00000

02011   76 0 00774      VORTER1 SLS   VORTIS1
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02012   76 0 01001      VORTER2 SLS   VORTIS2
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02013   76 0 00761      WINDERR SLS   REWIND
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| | | | | |
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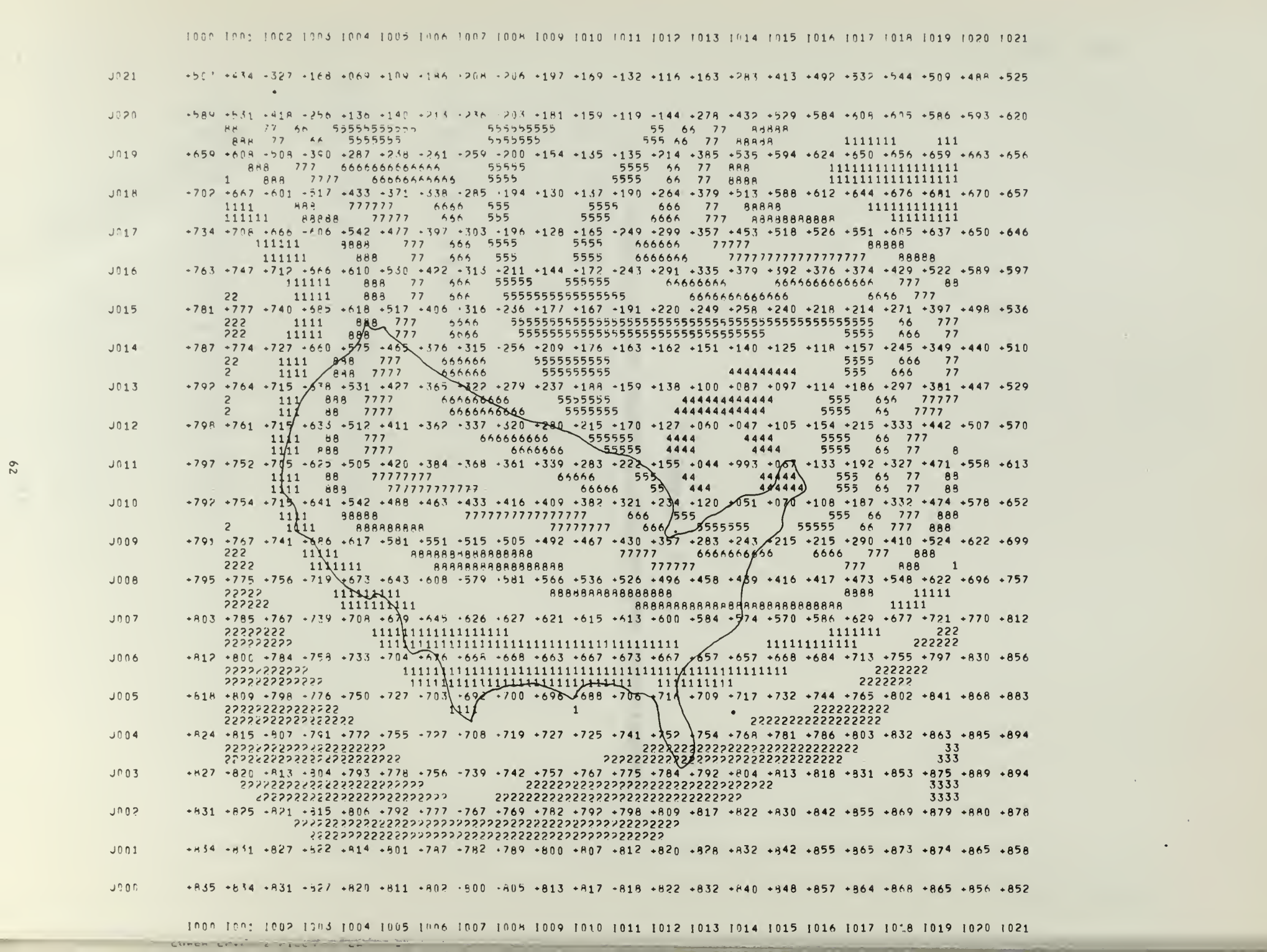
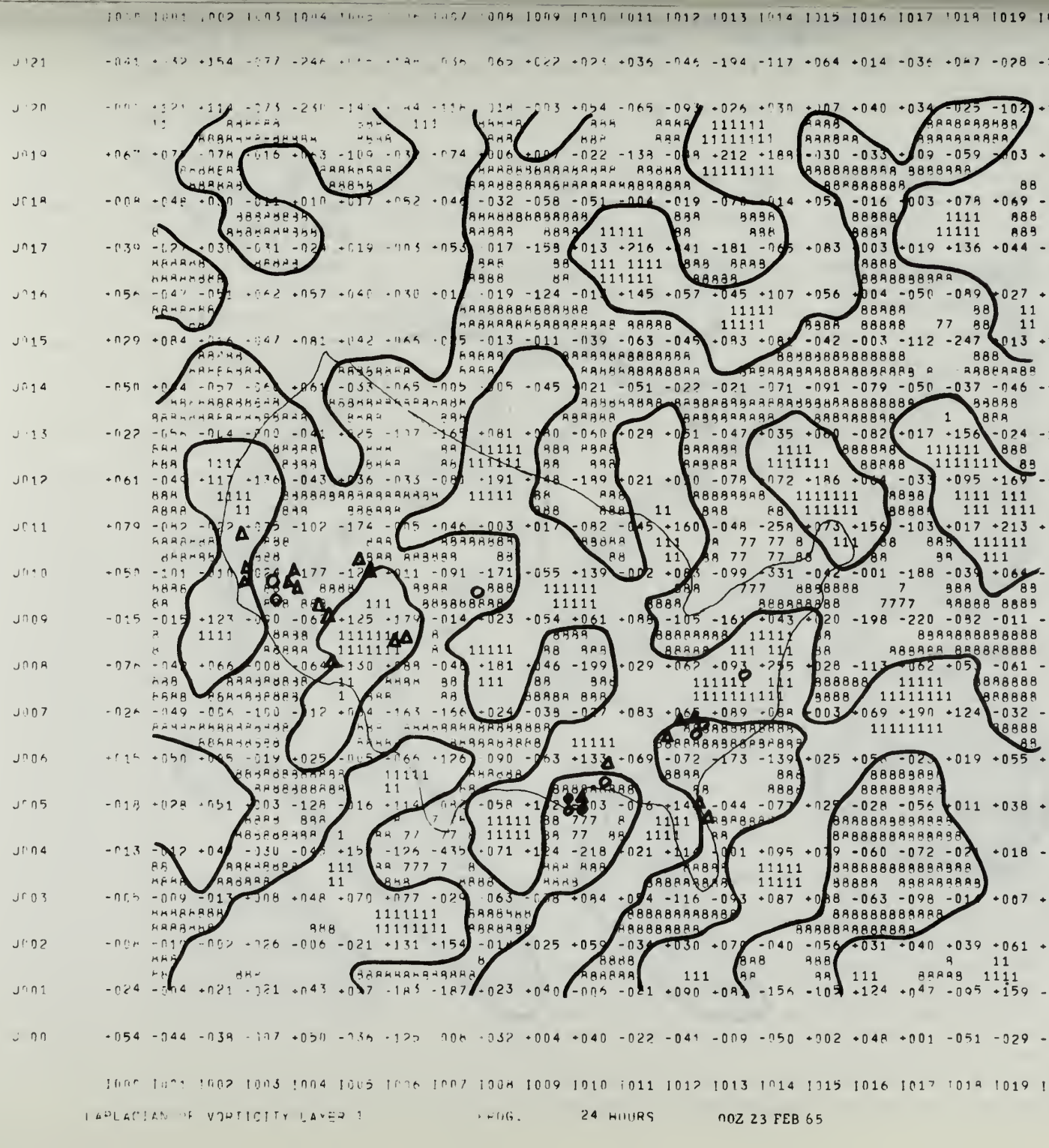
| 04423 | 04451 | SAD | LIB | SAD |
| 04451 | 04535 | SAH | LIB | SAH |
| 04535 | 04570 | SAI | LIB | SAI |
| 04570 | 04611 | SAJ | LIB | SAJ |
| 04611 | 04666 | SAR | LIB | SAR |
| 04666 | 04715 | VAB | LIB | VAB |
| 04715 | 04745 | WAB | LIB | WAB |
| 04745 | 05015 | WAE | LIB | WAE |
| 05015 | 14655 | FS0 | BSS | 4000 |
| 14655 | 24515 | FS1 | BSS | 4000 |
| 24515 | 34355 | FS2 | BSS | 4000 |
| 34355 | 44215 | FS3 | BSS | 4000 |
| 44215 | 54055 | FS4 | BSS | 4000 |
| 54055 | 63715 | FS5 | BSS | 4000 |
| 63715 | 73555 | FS6 | BSS | 4000 |
| 73555 | 00000 | | END | |

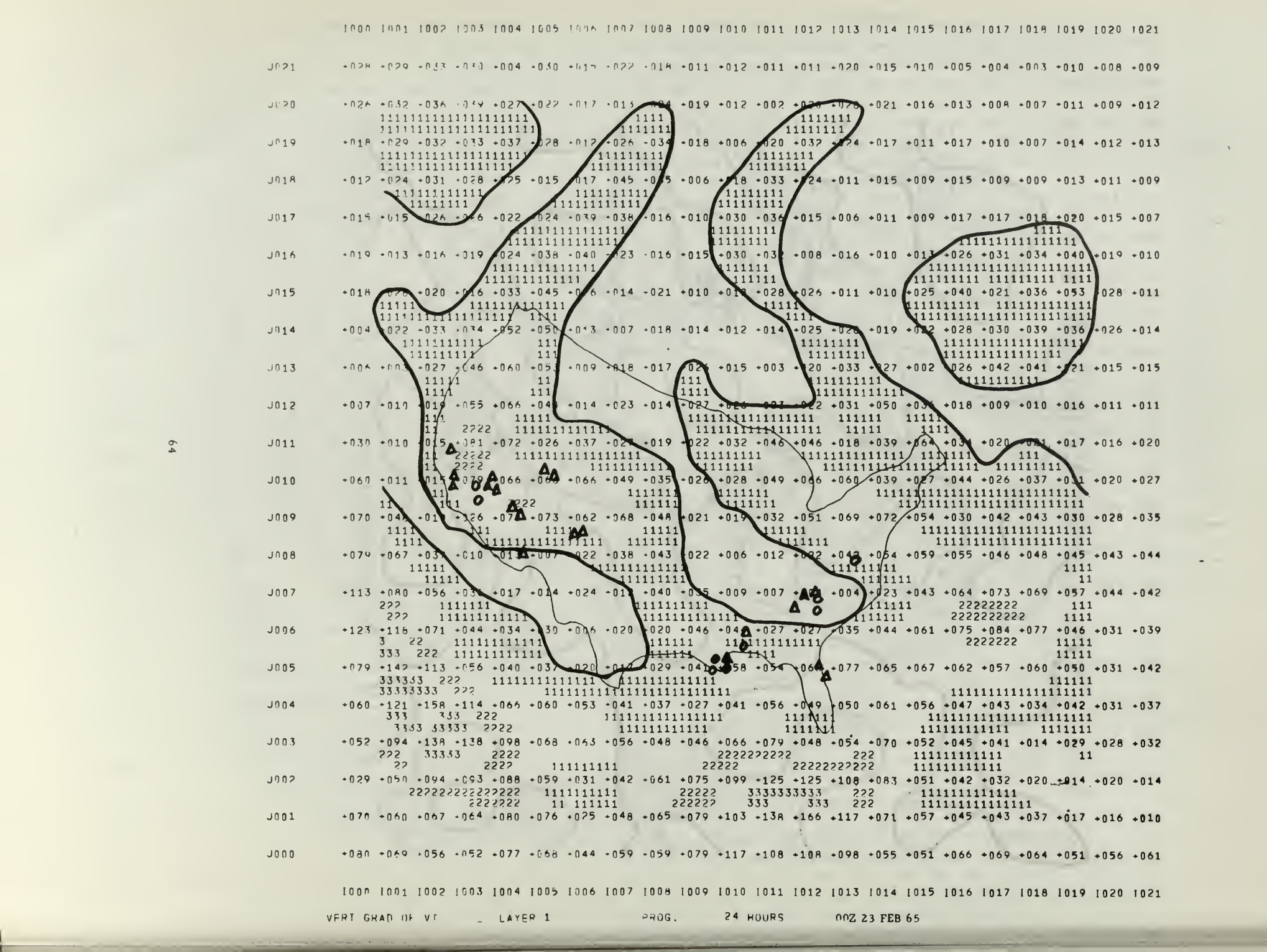
## 8. APPENDIX C

PRINTED FIELDS FROM THE RESEARCH PROGRAM FOR OOZ 23 FEB 65





LAPLACIAN OF VORTICITY LAYER 1 FCST. 24 HOURS 00Z 23 FEB 65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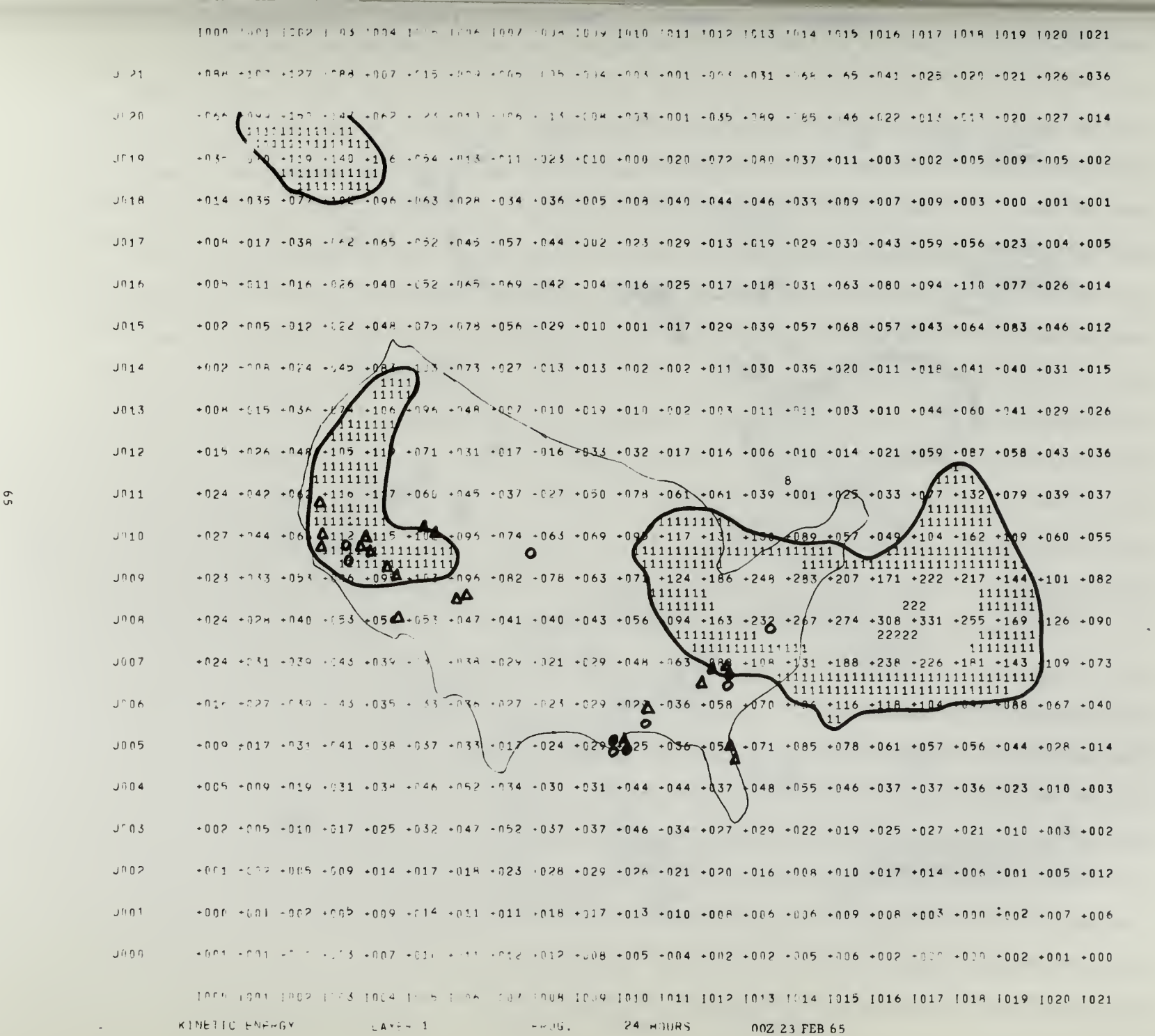
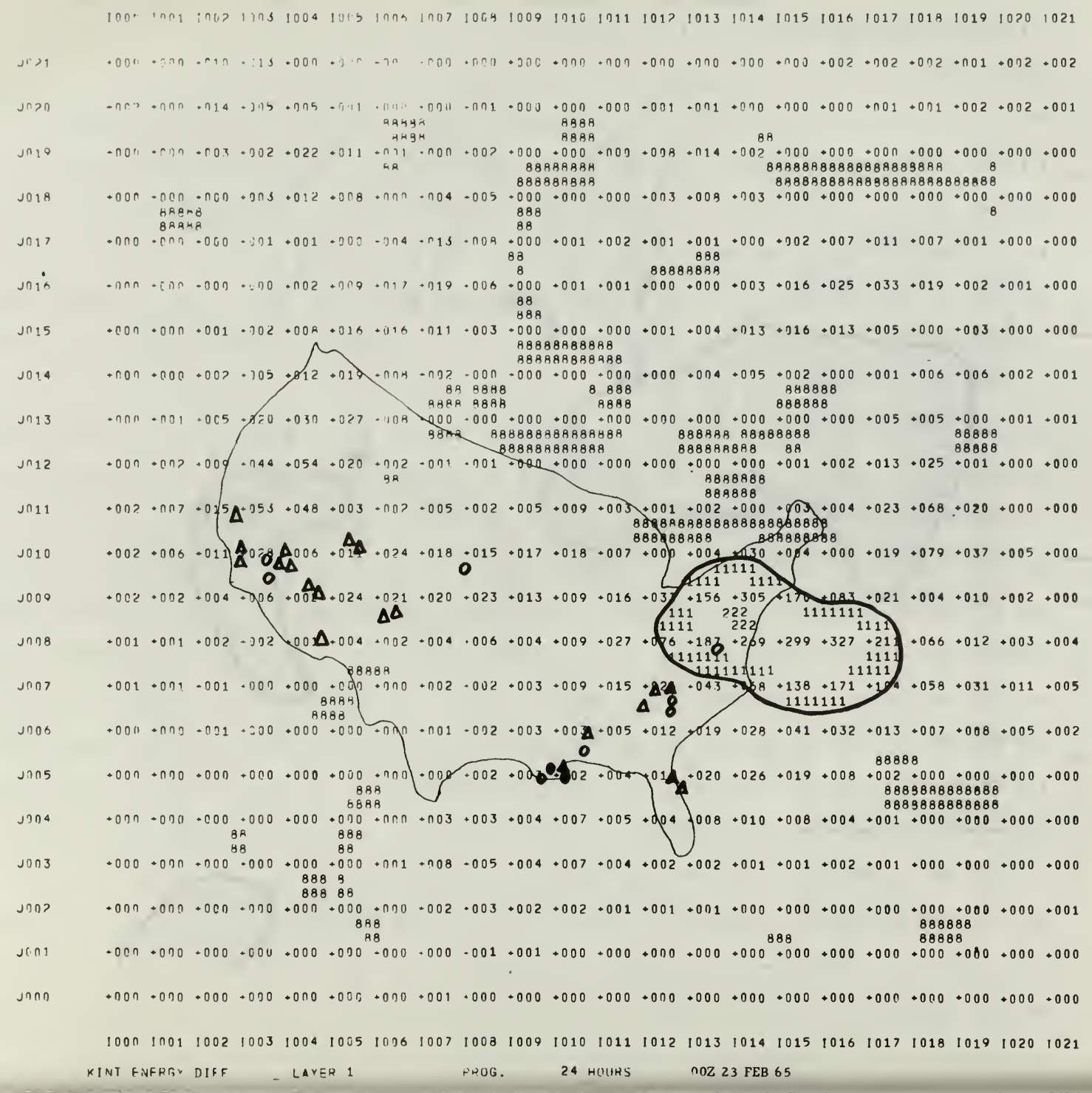
J000
I000 I001 I002 I003 I004 I005 I006 I007 I008 I009 I010 I011 I012 I013 I014 I015 I016 I017 I018 I019 I020 I021
VERT GRAD OF VT - LAYER 1 PROG. 24 HOURS 00Z 23 FEB 65



KINETIC ENERGY LAYER 1 PROG. 24 HOURS 00Z 23 FEB 65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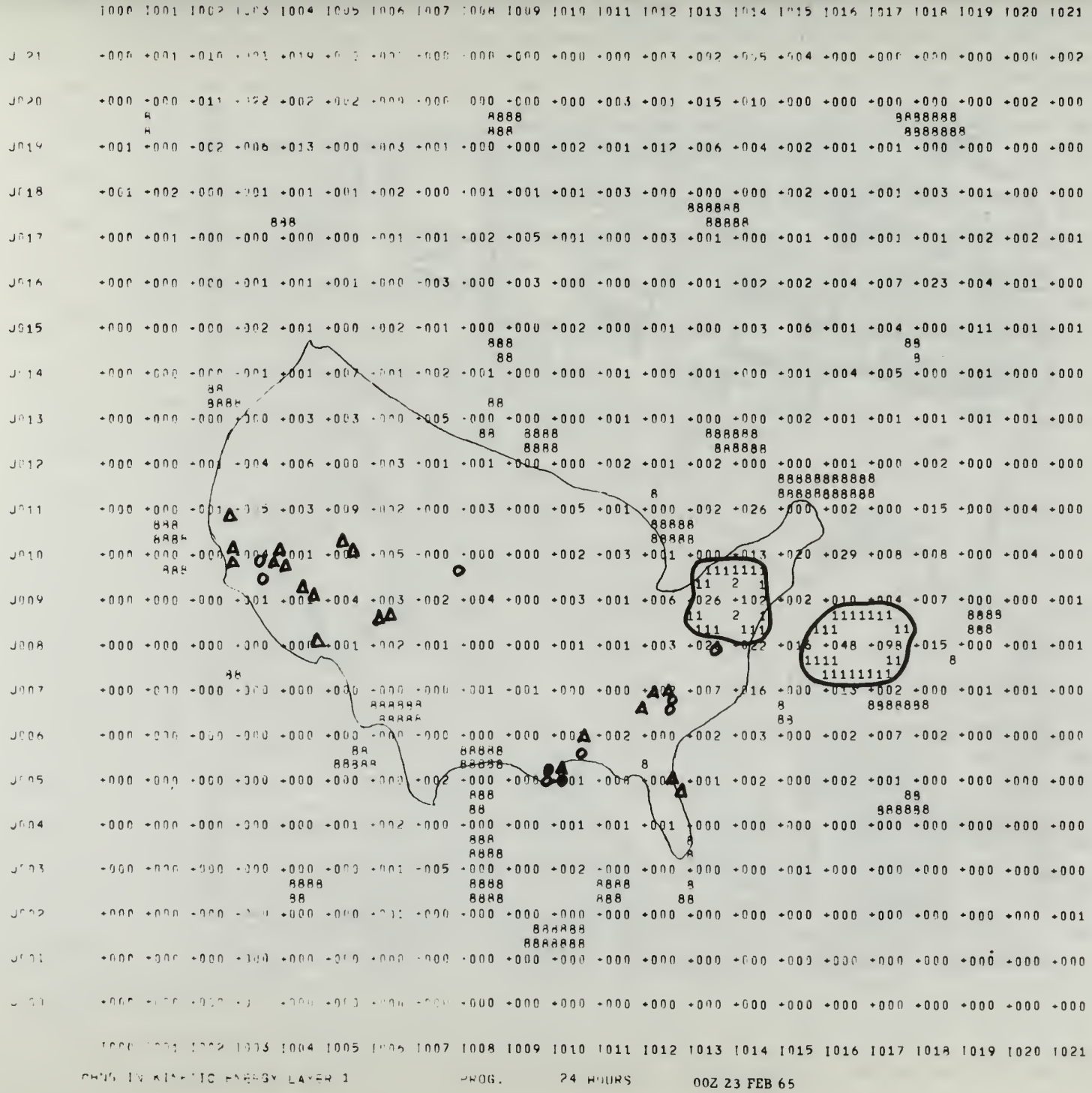
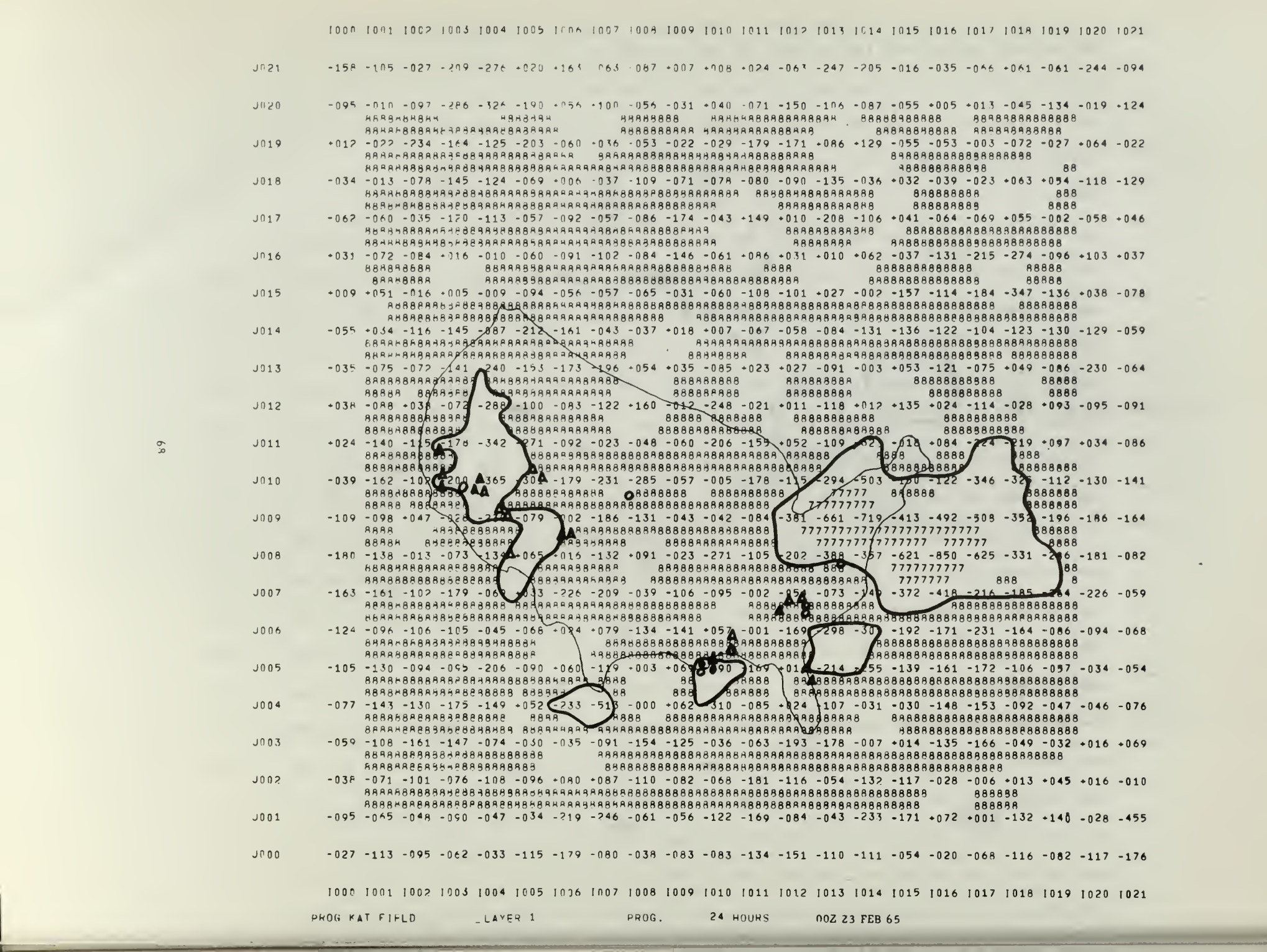

CHG IN KINETIC ENERGY LAYER 1
PROG. 24 HOURS
00Z 23 FEB 65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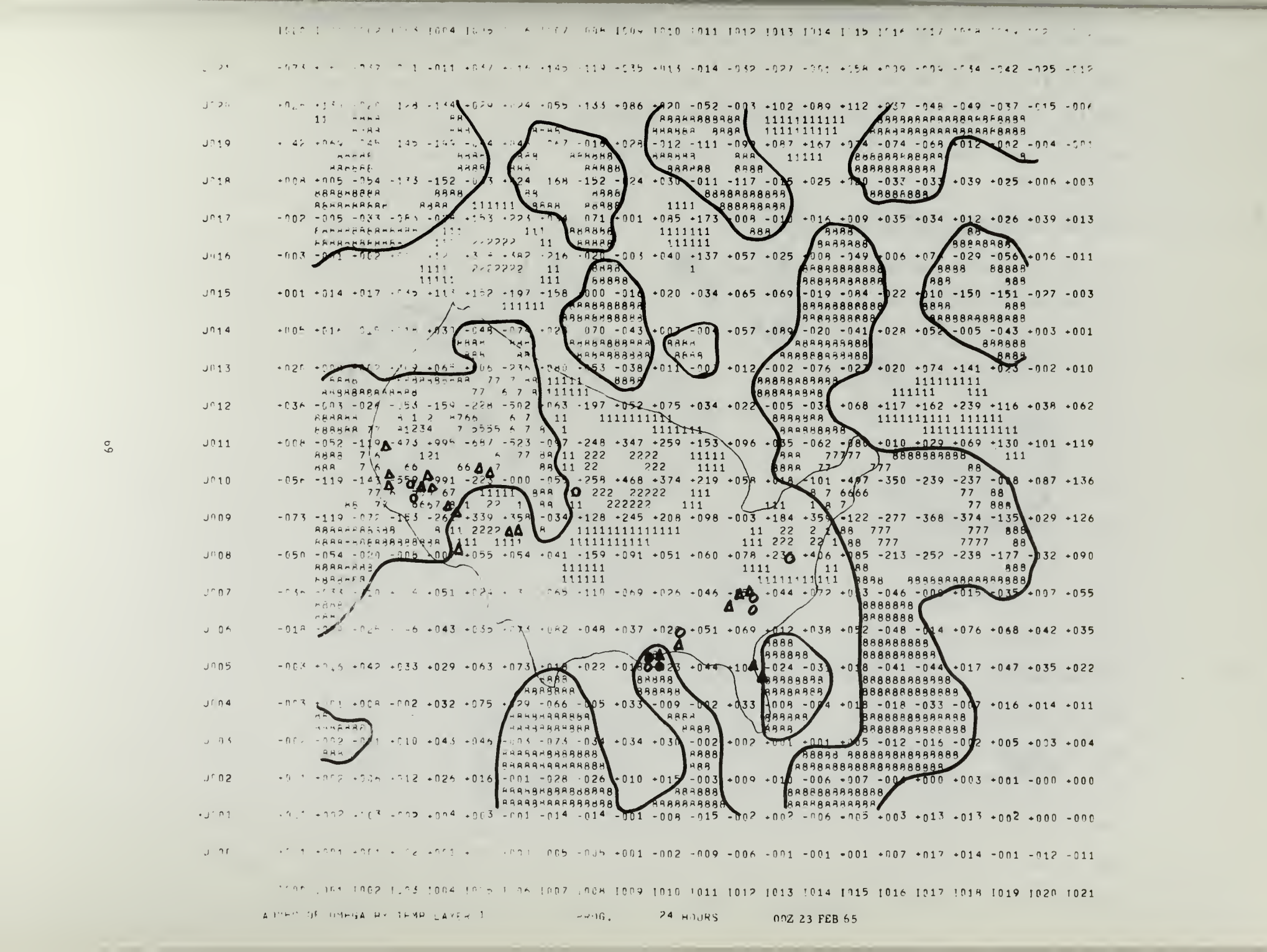
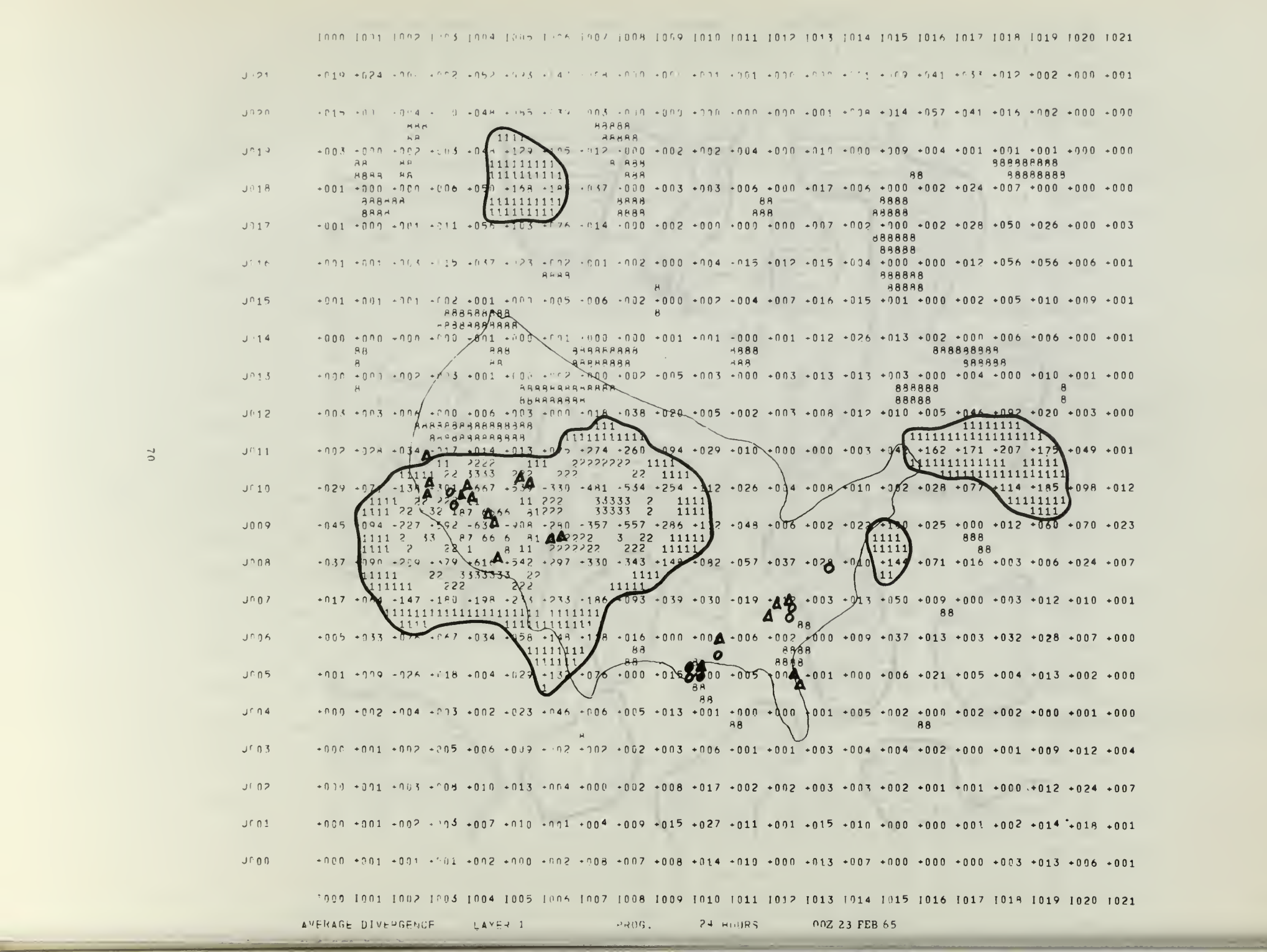
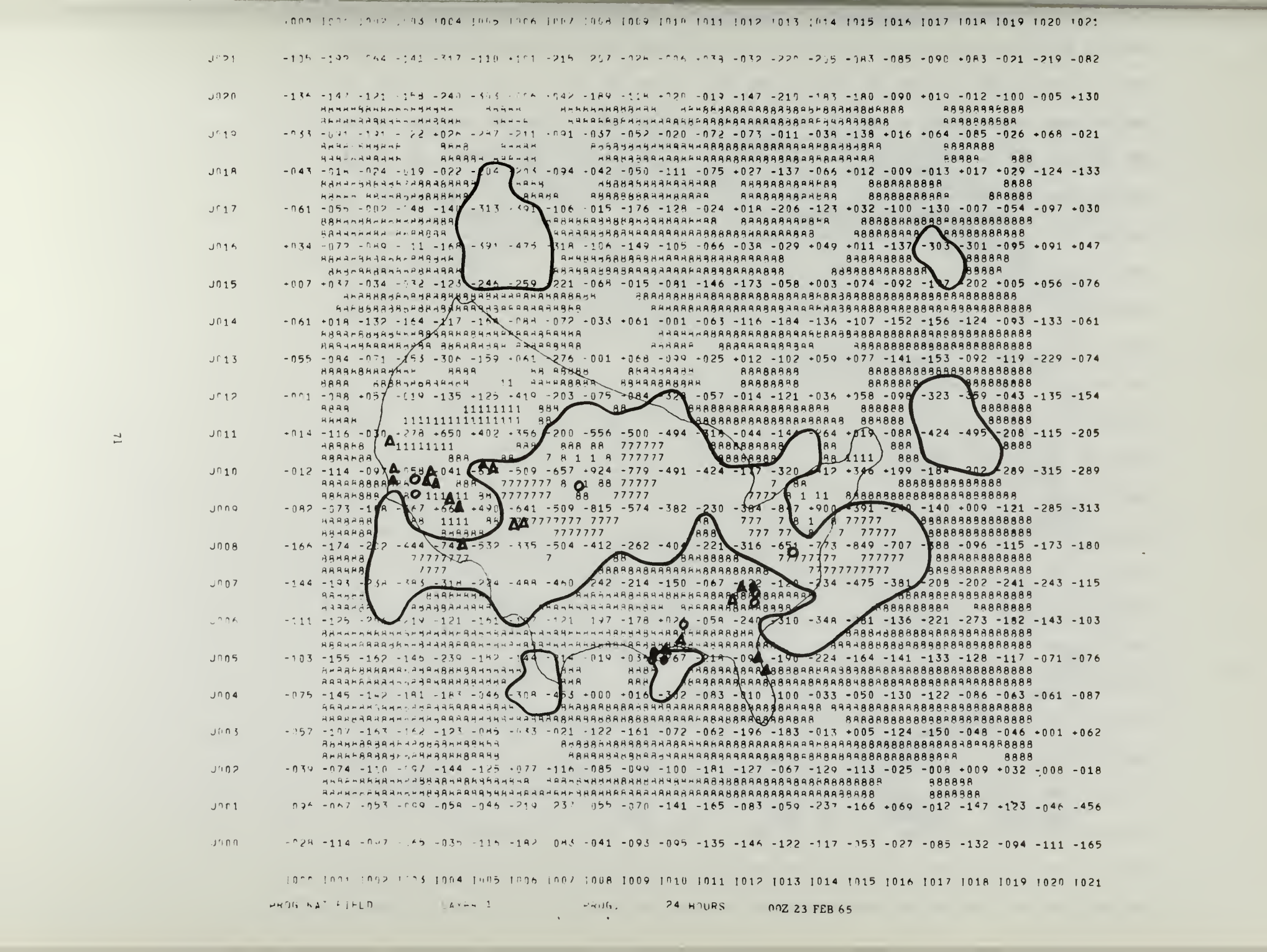
PROG KAT FIELD _LAYER 1 PROG. 24 HOURS 00Z 23 FEB 65

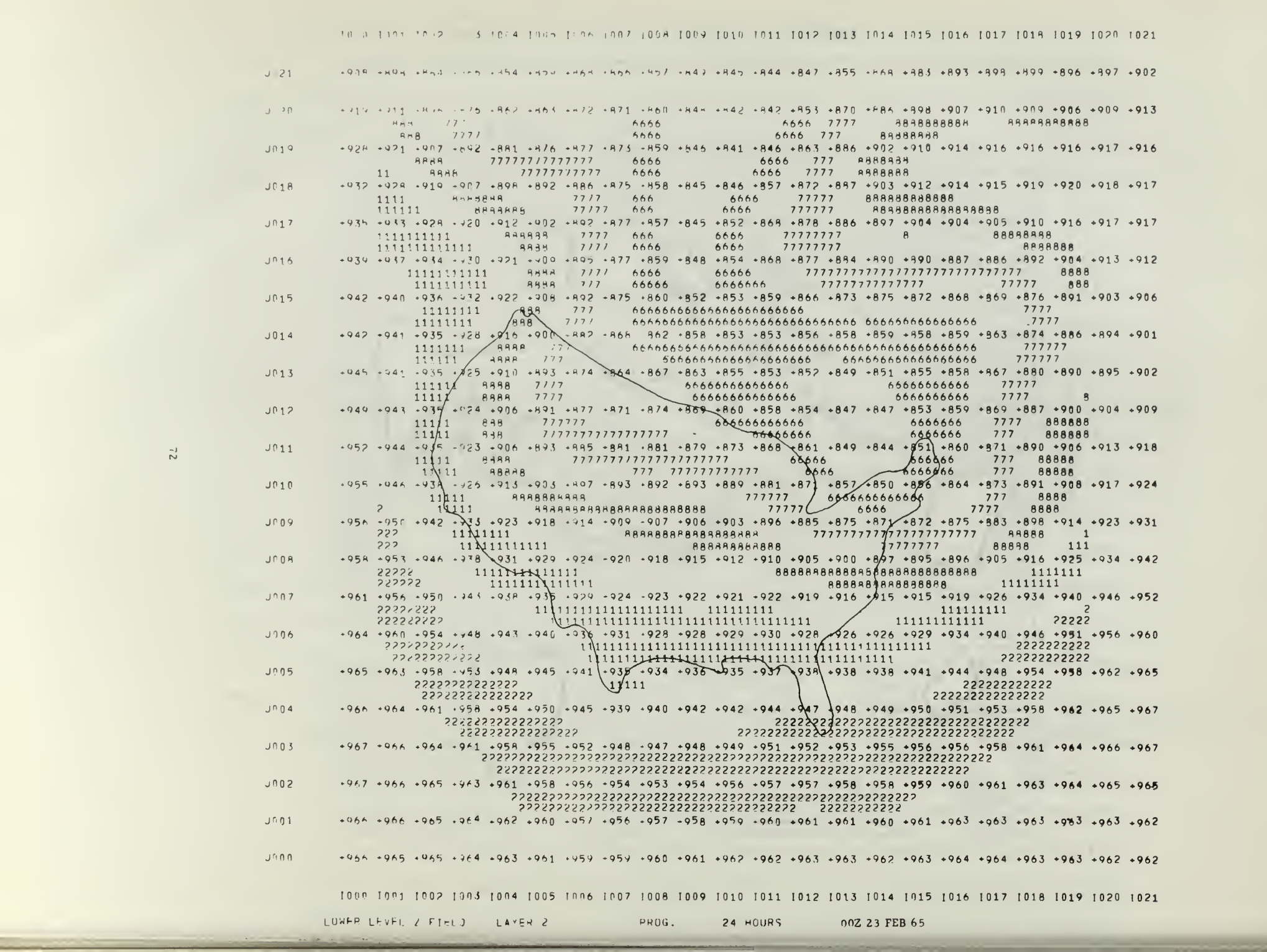


ADVECTION OF OMEGA BY TEMP LAYER 1 PROG. 24 HOURS 00Z 23 FEB 65


AVERAGE DIVERGENCE LAYER 1 PROG. 24 HOURS 00Z 23 FEB 65



PROG MAP FIELD LAYER 1 PROG. 24 HOURS 00Z 23 FEB 65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J009
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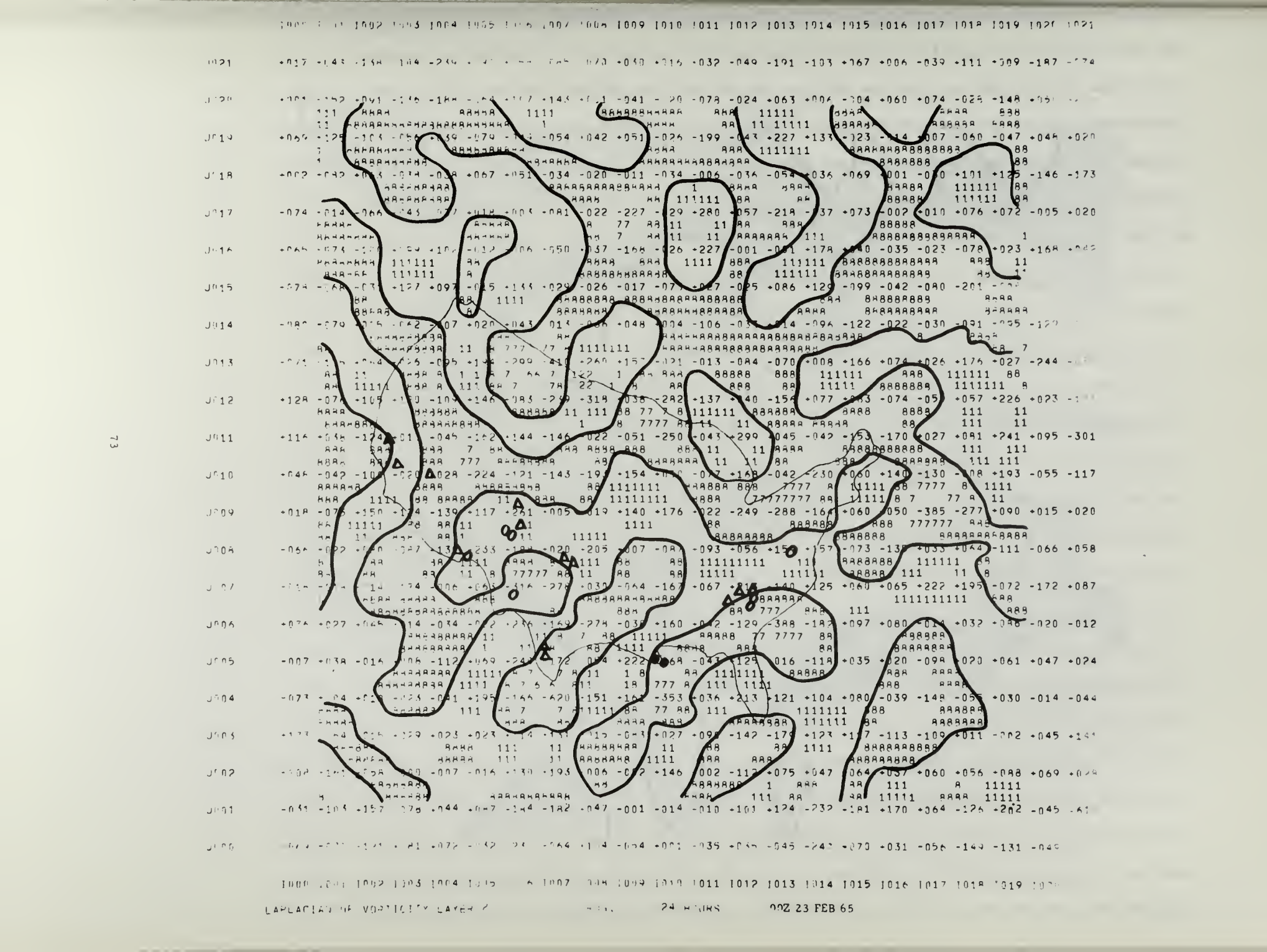
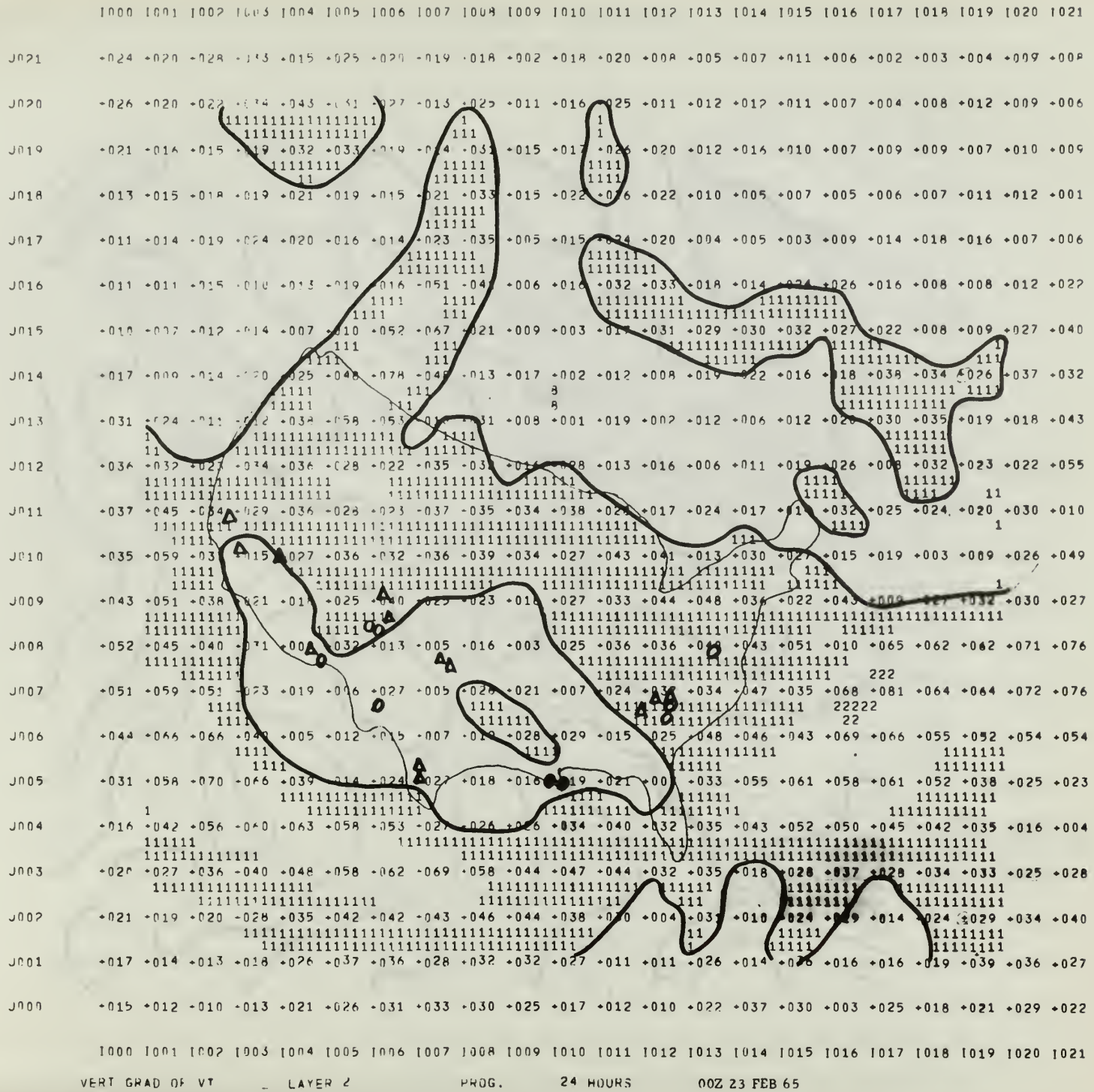
J001
J000
LOWER LEVEL / FIELD LAYER 2 PROG. 24 HOURS 00Z 23 FEB 65



LAPLACIAN OF VORTICITY LAYER 2 24 HOURS 00Z 23 FEB 65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J010
J009
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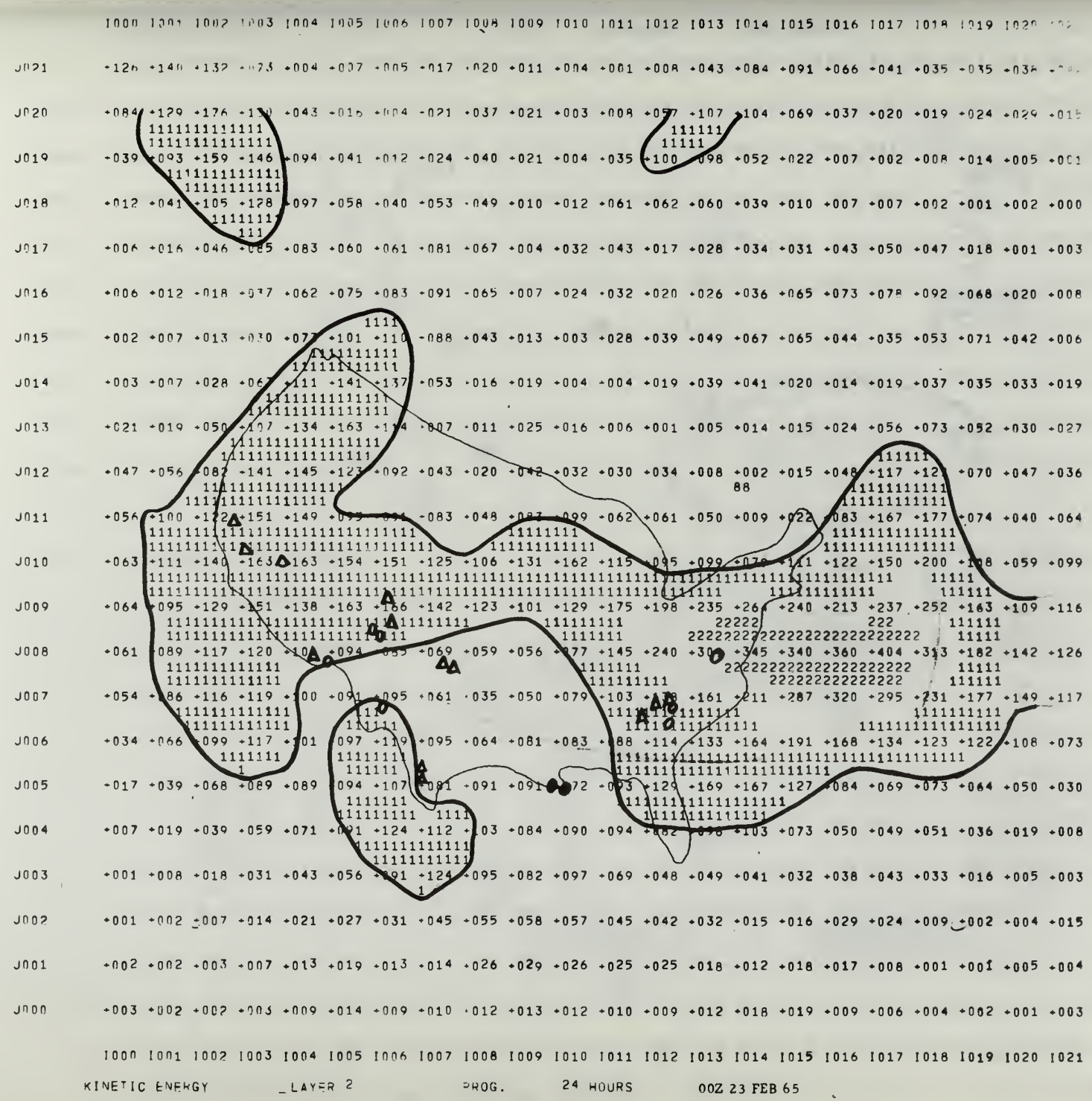
VERT GRAD OF VT _ LAYER 2 PROG. 24 HOURS 00Z 23 FEB 65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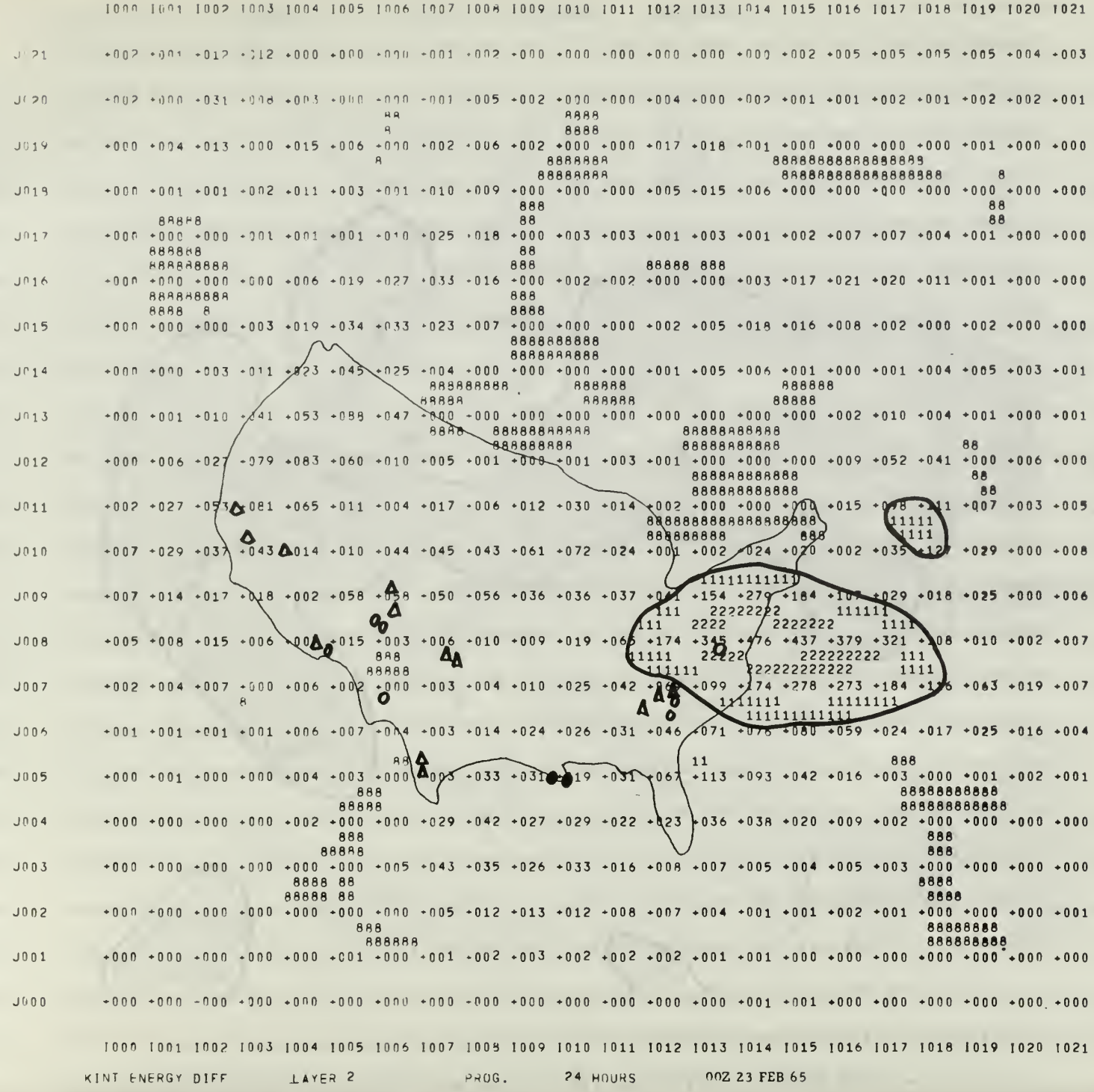
KINETIC ENERGY _LAYER 2 PROG. 24 HOURS 00Z 23 FEB 65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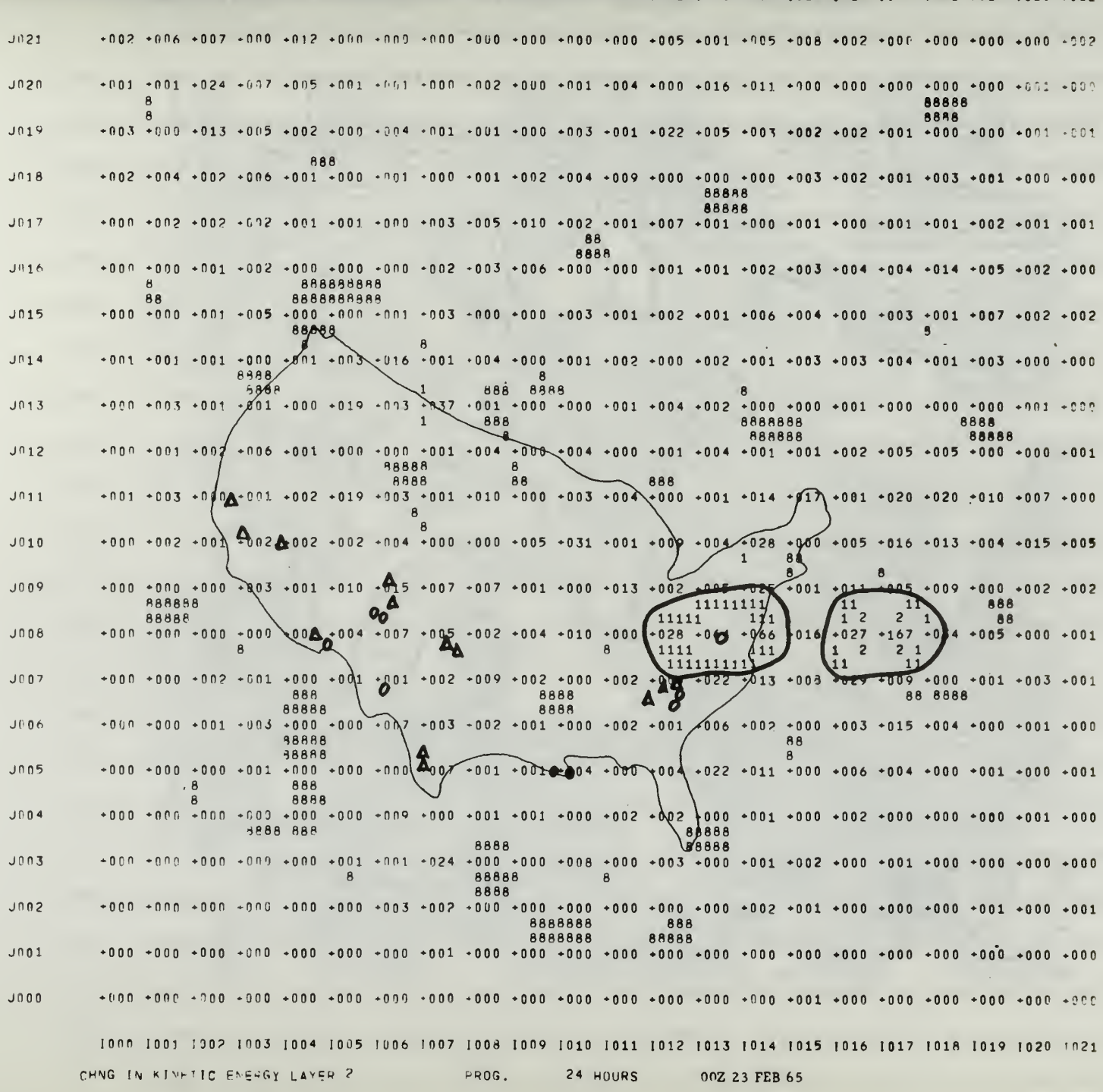
KINT ENERGY DIFF
LAYER 2
PROG.
24 HOURS
00Z 23 FEB 65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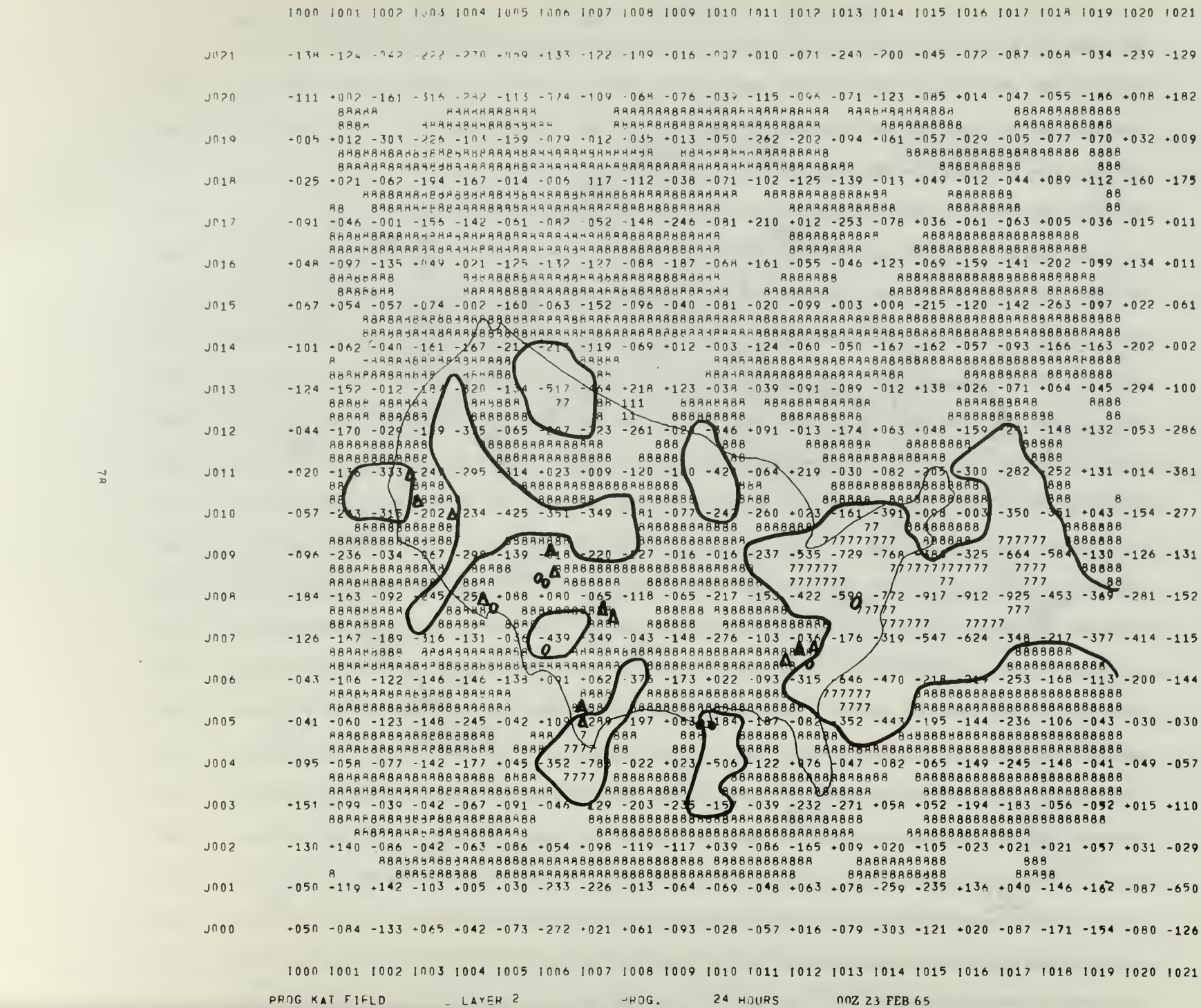
I000 I001 I002 I003 I004 I005 I006 I007 I008 I009 I010 I011 I012 I013 I014 I015 I016 I017 I018 I019 I020 I021
CHNG IN KINETIC ENERGY LAYER 2 PROG. 24 HOURS 00Z 23 FEB 65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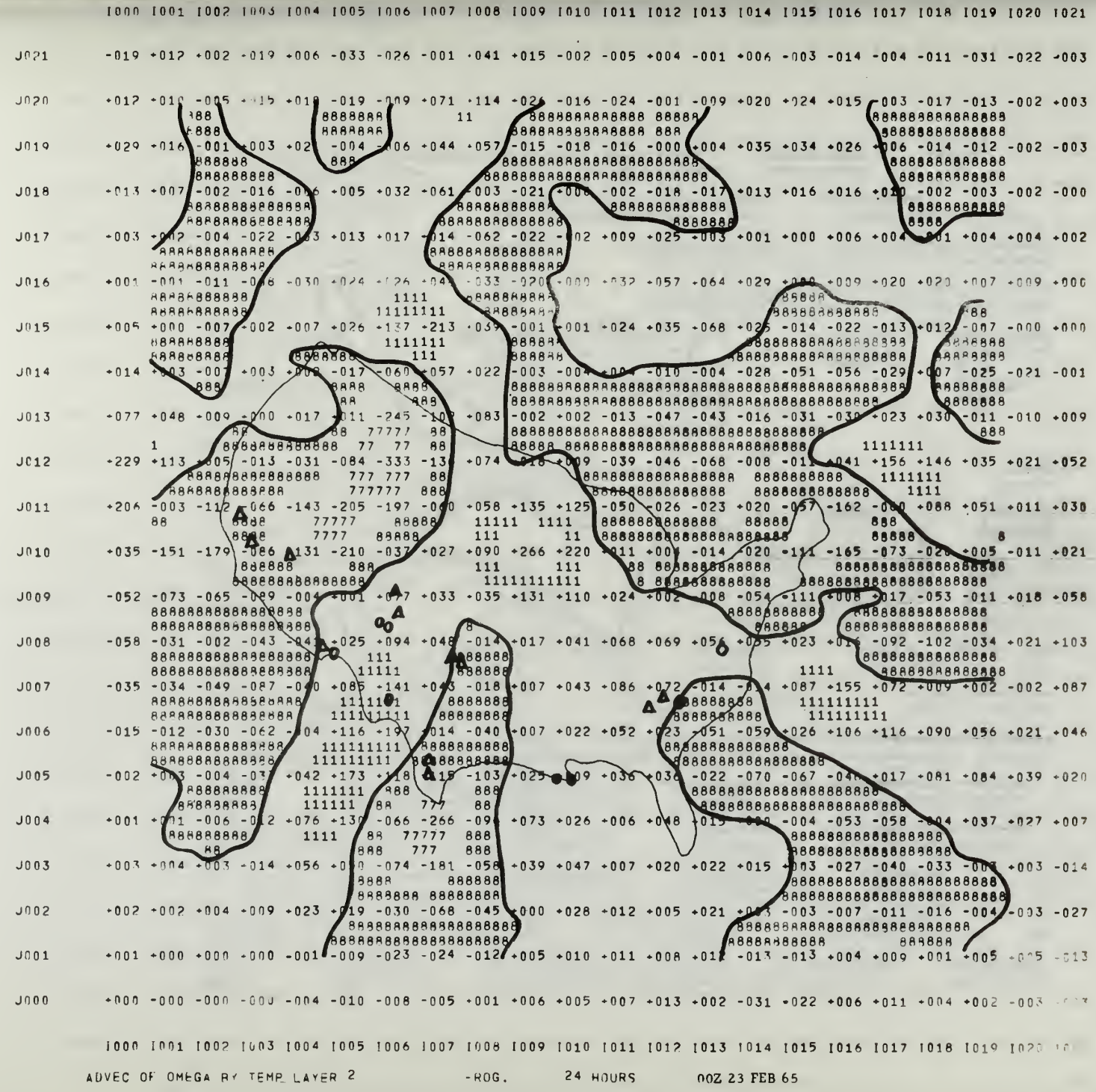
PROG KAT FIELD _ LAYER 2 PROG. 24 HOURS 00Z 23 FEB 65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J005 -002 +003 -004 -031 +042 +173 +118 +015 -103 +025 +009 +036 +036 -022 -070 -067 -040 +017 +081 +084 +039 +020
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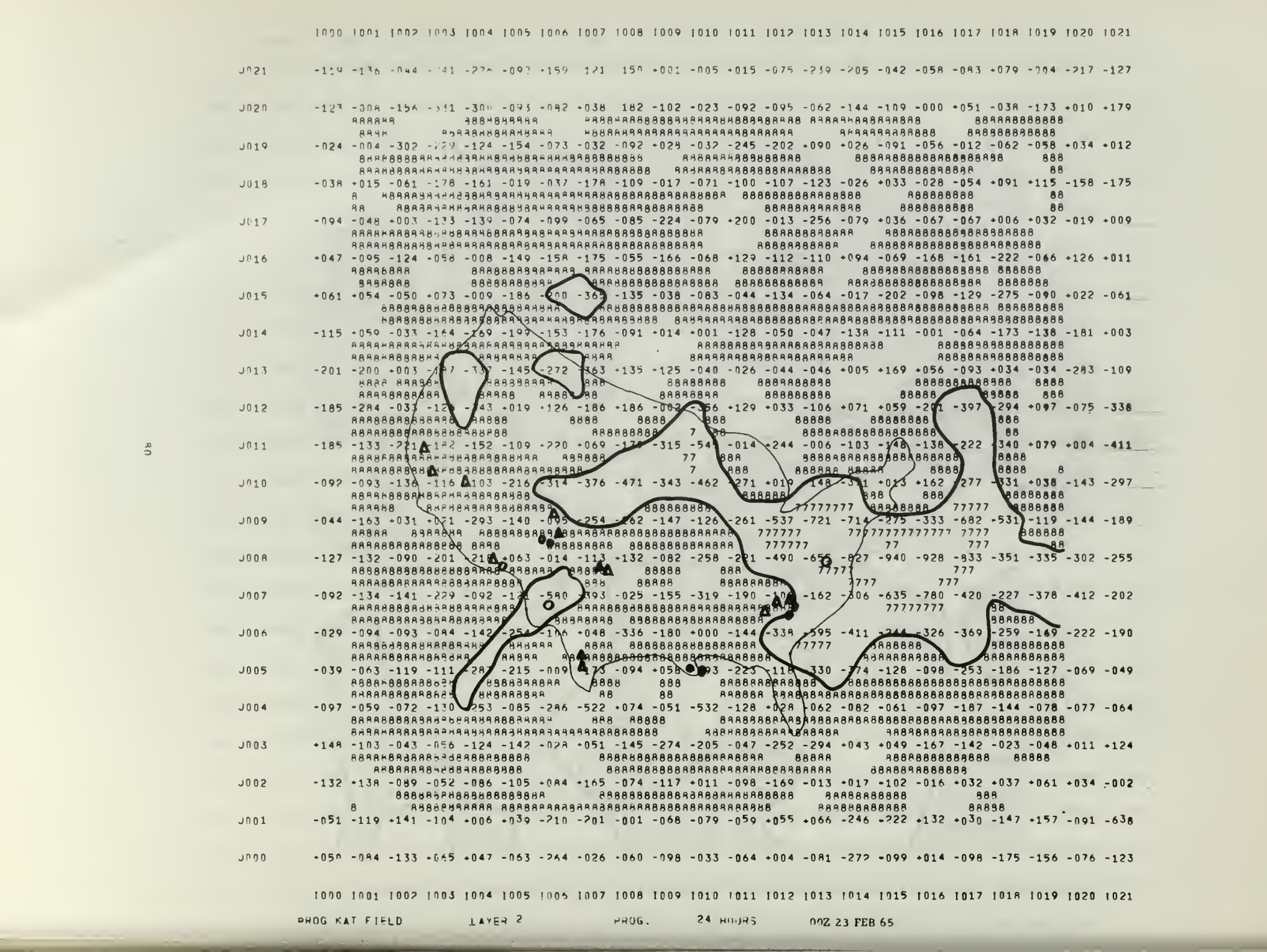
ADVEC OF OMEGA BY TEMP LAYER 2 -ROG. 24 HOURS 00Z 23 FEB 65


PROG KAT FIELD LAYER 2 PROG. 24 HOURS 00Z 23 FEB 65

# 9. APPENDIX D

## THE CLEAR AIR TURBULENCE FORECAST COMPUTER PROGRAM

```
                                                    KAT FORECAST
                                                    BEGIN STEERING PROGRAM
                                                    COMPUTES 500 TO 300 MB LAYER
                 00600              ORG     6000B
00600    20 0 01461          STA     TIME        PUT DATE TIME IN A REGISTER
         50 0 00000
00601    75 4 00674  START    RTJ     READD2      READS PACKED LOWER LEVEL D FIELD INTO
                                                  FS4
         50 0 00000
00602    75 4 00702  +       RTJ     UNPCKD2     UNPACKS LOWER LEVEL D FIELD INTO FS1
         50 0 00000
00603    75 4 00722  +       RTJ     READT2      READS LOWER LEVEL TEMPERATURE FIELD
                                                  INTO FS4
         50 0 00000
00604    75 4 00730  +       RTJ     UNPCKT2     UNPACKS LOWER LEVEL TEMPERATURE FIELD
                                                  INTO FS3
         50 0 00000
00605    75 4 00661  +       RTJ     READD1      READS PACKED UPPER LEVEL D FIELD INTO
                                                  FS4
         50 0 00000
00606    75 4 00667  +       RTJ     UNPCKD1     UNPACKS UPPER LEVEL D FIELD INTO FS0
         50 0 00000
00607    75 4 00707  +       RTJ     READT1      READS UPPER LEVEL TEMPERATURE FIELD IN
                                                  TO FS4
         50 0 00000
00610    75 4 00715  +       RTJ     UNPCKT1     UNPACKS UPPER LEVEL TEMPERATURE FIELD
                                                  INTO FS2
         50 0 00000
00611    75 4 00735  +       RTJ     REWIND      REWINDS TU 3 CH 5/6
         50 0 00000
00612    75 4 00741  +       RTJ     REWIND1     REWINDS TU 2 CH 5/6
         50 0 00000
00613    75 4 01274  +       RTJ     PRINT       PRINTS LOWER HEIGHT FIELD
         50 0 00000
00614    75 4 00745  +       RTJ     SINF        GENERATES SINE FIELD STOWS IN FS4
         50 0 00000
00615    75 4 00750  +       RTJ     VORTIS1     COMPUTES VORTICITY FIELD FROM UPPER
                                                  LEVEL D FIELD STOWS IN FS5
         50 0 00000
00616    75 4 00755  +       RTJ     VORTIS2     COMPUTES VORTICITY FIELD FROM LOWER
                                                  LEVEL D FIELD STOWS IN FS6
         50 0 00000
00617    75 4 00762  +       RTJ     LAPLAC1     COMPUTES LAPLACIAN OF UPPER LEVEL VORT
                                                  ICITY FIELD STOWS IN FS0
         50 0 00000
00620    75 4 00770  +       RTJ     LAPLAC2     COMPUTES LAPLACIAN OF LOWER LEVEL VORT
                                                  ICITY FIELD STOWS IN FS1
         50 0 00000
```

| | | | | | |
|---|---|---|---|---|---|
| 00621 | 75 4 00776<br>50 0 00000 | + | RTJ | HORIZ | COMPUTES AVERAGE LAPLACIAN BETWEEN UPPER AND LOWER LEVELS STOWS IN FS5 |
| 00622 | 75 4 01320<br>50 0 00000 | + | RTJ | PRINT1 | PRINTS LAPLACIAN OF VORTICITY |
| 00623 | 75 4 01003<br>50 0 00000 | + | RTJ | MHAT | STOWS SCALED MAP FACTOR IN FS6 |
| 00624 | 75 4 01011<br>50 0 00000 | + | RTJ | UTHM1 | COMPUTES U COMPONENT OF THERMAL WIND AT LOWER LEVEL STOWS IN FS0 |
| 00625 | 75 4 01027<br>50 0 00000 | + | RTJ | UTHM2 | COMPUTES U COMPONENT OF THERMAL WIND AT LOWER LEVEL STOWS IN FS1 |
| 00626 | 75 4 01045<br>50 0 00000 | + | RTJ | DUTHM | COMPUTES U COMPONENT DIFFERANCE BETWEEN UPPER AND LOWER LEVELS STOWS IN FS0 |
| 00627 | 75 4 01052<br>50 0 00000 | + | RTJ | VTHM1 | COMPUTES V COMPONENT OF THERMAL WIND AT LOWER LEVEL STOWS IN FS1 |
| 00630 | 75 4 01070<br>50 0 00000 | + | RTJ | VTHM2 | COMPUTES V COMPONENT OF THERMAL WIND AT UPPER LEVEL STOWS IN FS2 |
| 00631 | 75 4 01106<br>50 0 00000 | + | RTJ | DVTHM | COMPUTES V COMPONENT DIFFERANCE BETWEEN UPPER AND LOWER LEVELS STOWS IN FS1 |
| 00632 | 75 4 01113<br>50 0 00000 | + | RTJ | DTHM | COMPUTES VERTICAL GRADIENT OF THERMAL WIND STOWS IN FS0 |
| 00633 | 75 4 01343<br>50 0 00000 | + | RTJ | PRINT2 | PRINTS VERTICAL GRADIENT OF VT |
| 00634 | 75 4 01123<br>50 0 00000 | + | RTJ | KAT1 | HORIZ MINUS DTHM STOWS IN FS5 |
| 00635 | 75 4 00674<br>50 0 00000 | + | RTJ | READD2 | SEE ABOVE |
| 00636 | 75 4 00702<br>50 0 00000 | + | RTJ | UNPCKD2 | SEE ABOVE |
| 00637 | 75 4 00661<br>50 0 00000 | + | RTJ | READD1 | SEE ABOVE |
| 00640 | 75 4 00667<br>50 0 00000 | + | RTJ | UNPCKD1 | SEE ABOVE |
| 00641 | 75 4 00735<br>50 0 00000 | + | RTJ | REWIND | REWINDS TO 3 CH 5/6 |
| 00642 | 75 4 00741<br>50 0 00000 | + | RTJ | REWIND1 | REWINDS TO 2 CH 5/6 |
| 00643 | 75 4 00745<br>50 0 00000 | + | RTJ | SINF | SEE ABOVE |

```
00644   75 4 01003      +       RTJ     MHAT        SEE ABOVE
        50 0 00000

00645   75 4 01130      +       RTJ     UGEOS1      COMPUTES U COMPONENT OF GEOSTROPHIC
                                                    WIND AT UPPER LEVEL STOWS IN FS2
        50 0 00000

00646   75 4 01146      +       RTJ     UGEOS2      COMPUTES U COMPONENT OF GEOSTROPHIC
                                                    WIND AT LOWER LEVEL STOWS IN FS3
        50 0 00000

00647   75 4 01164      +       RTJ     UGEOS       COMPUTES AVERAGE U COMPONENT STOWS
                                                    IN FS2
        50 0 00000

00650   75 4 01173      +       RTJ     VGEOS1      COMPUTES V COMPONENT OF GEOSTROPHIC
                                                    WIND AT UPPER LEVEL STOWS IN FS3
        50 0 00000

00651   75 4 01211      +       RTJ     VGEOS2      COMPUTES V COMPONENT OF GEOSTROPHIC
                                                    WIND AT LOWER LEVEL STOWS IN FS4
        50 0 00000

00652   75 4 01227      +       RTJ     VGEOS       COMPUTES AVERAGE V COMPONENT STOWS
                                                    IN FS0
        50 0 00000

00653   75 4 01236      +       RTJ     KINETIC     COMPUTES V SQUARE STOWS IN FS0
                                                    COMPUTES V SQ DIFF STOWS IN FS4
        50 0 00000

00654   75 4 01366      +       RTJ     PRINT3      PRINTS KINETIC ENERGY FIELD
        50 0 00000

00655   75 4 01246      +       RTJ     KAT2        STOWS PREVIOUS TERMS IN FS0
        50 0 00000

00656   75 4 01411      +       RTJ     PRINT4      PRINTS PROG KAT FIELD
        50 0 00000

00657   75 4 01253      +       RTJ     LAYER2      COMPUTES 300 TO 200 MB LAYER
        50 0 00000

00660   76 0 00000      +       SLS                 END OF STEERING PROGRAM USES OFF LINE
                                                    PRINTING
        50 0 00000

00661   75 0 00000      READD1  SLJ     **
        50 0 00000

00662   12 0 01461      +       LDA     TIME
        16 0 01436              LDQ     NAME1

00663   75 4 03707      +       RTJ     MAG
        00 0 00000              00      0,0

00664   50 0 01472      HIGHD   ENI     MAA
        50 0 01300              ENI     1300B

00665   50 0 43641              ENI     FS4
        50 0 01465              ENI     READERR

00666   75 0 00661              SLJ     READD1
        50 0 00000

00667   75 0 00000      UNPCKD1 SLJ     **
        50 6 00000              ENI     0,6
```

```
00670   75 0 00672      +       SLJ     *+2
        00 0 43641              00      FS4

00671   00 0 04441              00      FS0
        00 0 02453              00      2453B

00672   75 4 04341      +       RTJ     WAT
        50 0 00007              ENI     7

00673   75 0 00667              SLJ     UNPCKD1
        50 0 00000

00674   75 0 00000      READD2  SLJ     **
        50 0 00000

00675   12 0 01461      +       LDA     TIME
        16 0 01440              LDQ     NAME2

00676   75 4 03707      +       RTJ     MAG
        00 0 00000              00      0,0

00677   50 0 01472              ENI     MAA
        50 0 01300              ENI     1300B

00700   50 0 43641              ENI     FS4
        50 0 01465              ENI     READERR

00701   75 0 00674              SLJ     READD2
        50 0 00000

00702   75 0 00000      UNPCKD2 SLJ     **
        50 6 00000              ENI     0,6

00703   75 1 00705      +       SLJ     *+2
        00 1 43641              00      FS4

00704   00 0 14301              00      FS1
        00 0 02453              00      2453B

00705   75 4 04341      +       RTJ     WAB
        50 0 00007              ENI     7

00706   75 0 00702              SLJ     UNPCKD2
        50 0 00000

00707   75 0 00000      READT1  SLJ     **
        50 0 00000

00710   12 0 01461      +       LDA     TIME
        16 0 01442              LDQ     NAME3

00711   75 4 03707      +       RTJ     MAG
        00 0 00000              00      0,0

00712   50 0 01472      HIGHT   ENI     MAA
        50 0 01300              ENI     1300B

00713   50 0 43641              ENI     FS4
        50 0 01465              ENI     READERR

00714   75 0 00707              SLJ     READT1
        50 0 00000

00715   75 0 00000      UNPCKT1 SLJ     **
        50 6 00000              ENI     0,6

00716   75 0 00720      +       SLJ     *+2
        00 0 43641              00      FS4

00717   00 0 24141              00      FS2
        00 0 02453              00      2453B
```

```
00720   75 4 04241      +         RTJ     WAB
        50 0 00007                ENI     7
00721   75 0 00715                SLJ     UNPCKT1
        50 0 00000
00722   75 0 00000      READT2    SLJ     **
        50 0 00000
00723   12 0 01461      +         LDA     TIME
        16 0 01444                LDQ     NAME4
00724   75 4 03707      +         RTJ     MAG
        00 0 00000                00      0,0
00725   50 0 01472                ENI     MAA
        50 0 01300                ENI     1300B
00726   50 0 43641                ENI     FS4
        50 0 01465                ENI     READERR
00727   75 0 00722                SLJ     READT2
        50 0 00000
00730   75 0 00000      UNPCKT2   SLJ     **
        50 6 00000                ENI     0,6
00731   75 0 00733      +         SLJ     *+2
        00 0 43641                00      FS4
00732   00 0 34001                00      FS3
        00 0 02453                00      2453B
00733   75 4 04341      +         RTJ     WAB
        50 0 00007                ENI     7
00734   75 0 00730                SLJ     UNPCKT2
        50 0 00000
00735   75 0 00000      REWIND    SLJ     **
        50 0 00000
00736   75 4 01472      +         RTJ     MAA
        00 0 11306                00      11306B
00737   75 0 00735      +         SLJ     REWIND
        50 0 00000
00740   75 0 01471      +         SLJ     WINDERR
        50 0 00000
00741   75 0 00000      REWIND1   SLJ     **
        50 0 00000
00742   75 4 01472      +         RTJ     MAA
        00 0 11206                00      11206B
00743   75 0 00741      +         SLJ     REWIND1
        50 0 00000
00744   75 0 01471      +         SLJ     WINDERR
        50 0 00000
00745   75 0 00000      SINF      SLJ     **
        50 0 00000
00746   75 4 04161      +         RTJ     SAI
        50 0 43641                ENI     FS4
00747   75 0 00745      +         SLJ     SINF
        50 0 00000
```

```
00750   75 4 00000      VORTIS1  SLJ     **
        50 4 00000

00751   75 4 04235      +        RTJ     SAR
        50 0 43641               ENI     FS4

00752   50 0 04441               ENI     FS0
        50 0 53501               ENI     FS5

00753   50 0 01467               ENI     VORTER1
        50 0 04075               ENI     SAH

00754   75 0 00750               SLJ     VORTIS1
        50 0 00000

00755   75 0 00000      VORTIS2  SLJ     **
        50 0 00000

00756   75 4 04235      +        RTJ     SAR
        50 0 43641               ENI     FS4

00757   50 0 14301               ENI     FS1
        50 0 63341               ENI     FS6

00760   50 0 01470               ENI     VORTER2
        50 0 04075               ENI     SAH

00761   75 0 00755               SLJ     VORTIS2
        50 0 00000

00762   75 0 00000      LAPLAC1  SLJ     **
        50 0 00000

00763   75 4 04047      +        RTJ     SAD
        00 0 04441               00      FS0

00764   00 0 53501               00      FS5
        00 0 01463               00      LAPERR1

00765   75 4 04075      +        RTJ     SAH
        50 0 04073               ENI     SAD+24B

00766   50 0 04061               ENI     SAD+12B
        50 0 04061               ENI     SAD+12B

00767   75 0 00762               SLJ     LAPLAC1
        50 0 00000

00770   75 0 00000      LAPLAC2  SLJ     **
        50 0 00000

00771   75 4 04047      +        RTJ     SAD
        00 0 14301               00      FS1

00772   00 0 63341               00      FS6
        00 0 01464               00      LAPERR2

00773   75 4 04075      +        RTJ     SAH
        50 0 04073               ENI     SAD+24B

00774   50 0 04061               ENI     SAD+12B
        50 0 04061               ENI     SAD+12B

00775   75 0 00770               SLJ     LAPLAC2
        50 0 00000

00776   75 0 00000      HORIZ    SLJ     **
        50 4 00000               ENI     0,4

00777   12 4 04441      LOOP1    LDA     FS0,4
        14 4 14301               ADD     FS1,4
```

```
01000   01 0 00001          ARS   1
        20 4 53501          STA   FS5,4

01001   54 4 07600    +     ISK   7600B,4
        75 0 00777          SLJ   LOOP1

01002   75 0 00776          SLJ   HORIZ
        50 0 00000

01003   75 0 00000    MHAT  SLJ   **
        50 0 00000

01004   75 4 04214    +     RTJ   SAJ
        00 0 01462          00    HATERR

01005   50 4 43641          ENI   FS4
        50 0 63341          ENI   FS6

01006   75 4 04075    +     RTJ   SAH
        00 0 04223          00    SAJ+7B

01007   50 0 04223          ENI   SAJ+7B
        50 0 04223          ENI   SAJ+7B

01010   75 0 01003          SLJ   MHAT
        50 0 00000

01011   75 0 00000    UTHM1 SLJ   **
        50 0 00000

01012   75 4 04075    DIF1  RTJ   SAH
        00 0 01015          00    OUTSID1

01013   50 0 01017    +     ENI   INSID1
        50 0 01017          ENI   INSID1

01014   75 0 01011    +     SLJ   UTHM1
        50 0 00000

01015   10 0 00000    OUTSID1 ENA 0
        20 2 04441          STA   FS0,2

01016   75 0 01012          SLJ   DIF1
        50 0 00000

01017   12 2 43641    INSID1 LDA  FS4,2
        01 0 00001          ARS   1

01020   14 0 01434          ADD   CONST1
        20 0 01455          STA   LOCAT1

01021   26 0 01455          MUF   LOCAT1
        20 0 01455          STA   LOCAT1

01022   12 3 24141          LDA   FS2,3
        15 1 24141          SUB   FS2,1

01023   20 0 01456          STA   LOCAT2
        12 0 01435          LDA   CONST2

01024   26 2 63341          MUF   FS6,2
        26 0 01456          MUF   LOCAT2

01025   27 0 01455          DVF   LOCAT1
        27 2 24141          DVF   FS2,2

01026   20 2 04441          STA   FS0,2
        75 0 01012          SLJ   DIF1

01027   75 0 00000    UTHM2 SLJ   **
        50 0 00000
```

```
01030   75 4 04075      DIF2    RTJ     SAH
        00 0 01033              00      OUTSID2

01031   50 0 01035      +       ENI     INSID2
        50 0 01035              ENI     INSID2

01032   75 0 01027      +       SLJ     UTHM2
        50 0 00000

01033   10 0 00000      OUTSID2 ENA     0
        20 2 14301              STA     FS1,2

01034   75 0 01030              SLJ     DIF2
        50 0 00000

01035   12 2 43641      INSID2  LDA     FS4,2
        01 0 00001              ARS     1

01036   14 0 01434              ADD     CONST1
        20 0 01455              STA     LOCAT1

01037   26 0 01455              MUF     LOCAT1
        20 0 01455              STA     LOCAT1

01040   12 3 34001              LDA     FS3,3
        15 1 34001              SUB     FS3,1

01041   20 0 01456              STA     LOCAT2
        12 0 01435              LDA     CONST2

01042   26 2 63341              MUF     FS6,2
        26 0 01456              MUF     LOCAT2

01043   27 0 01455              DVF     LOCAT1
        27 2 34001              DVF     FS3,2

01044   20 2 14301              STA     FS1,2
        75 0 01030              SLJ     DIF2

01045   75 0 00000      OUTHM   SLJ     **
        50 4 00000              ENI     0,4

01046   12 4 04441      LOOP4   LDA     FS0,4
        15 4 14301              SUB     FS1,4

01047   20 4 04441              STA     FS0,4
        50 0 00000

01050   54 4 07600      +       ISK     7600B,4
        75 0 01046              SLJ     LOOP4

01051   75 0 01045              SLJ     OUTHM
        50 0 00000

01052   75 0 00000      VTHM1   SLJ     **
        50 0 00000

01053   75 4 04075      DIF3    RTJ     SAH
        00 0 01056              00      OUTSID3

01054   50 0 01060      +       ENI     INSID3
        50 0 01060              ENI     INSID3

01055   75 0 01052      +       SLJ     VTHM1
        50 0 00000

01056   10 0 00000      OUTSID3 ENA     0
        20 2 14301              STA     FS1,2

01057   75 0 01053              SLJ     DIF3
        50 0 00000
```

```
01060   12 2 43641      INSID3  LDA     FS4,2
        01 0 00001              ARS     1

01061   14 0 01434              ADD     CONST1
        20 0 01455              STA     LOCAT1

01062   26 0 01455              MUF     LOCAT1
        20 0 01455              STA     LOCAT1

01063   12 2 24142              LDA     FS2+1,2
        15 2 24140              SUB     FS2-1,2

01064   20 0 01456              STA     LOCAT2
        12 0 01435              LDA     CONST2

01065   26 2 63341              MUF     FS6,2
        26 0 01456              MUF     LOCAT2

01066   27 0 01455              DVF     LOCAT1
        27 2 24141              DVF     FS2,2

01067   20 2 14301              STA     FS1,2
        75 0 01053              SLJ     DIF3

01070   75 0 00000      VTHM2   SLJ     **
        50 0 00000

01071   75 4 04075      DIF4    RTJ     SAH
        00 0 01074              00      OUTSID4

01072   50 0 01076      +       ENI     INSID4
        50 0 01076              ENI     INSID4

01073   75 0 01070      +       SLJ     VTHM2
        50 0 00000

01074   10 0 00000      OUTSID4 ENA     0
        20 2 24141              STA     FS2,2

01075   75 0 01071              SLJ     DIF4
        50 0 00000

01076   12 2 43641      INSID4  LDA     FS4,2
        01 0 00001              ARS     1

01077   14 0 01434              ADD     CONST1
        20 0 01455              STA     LOCAT1

01100   26 0 01455              MUF     LOCAT1
        20 0 01455              STA     LOCAT1

01101   12 2 34002              LDA     FS3+1,2
        15 2 34000              SUB     FS3-1,2

01102   20 0 01456              STA     LOCAT2
        12 0 01435              LDA     CONST2

01103   26 2 63341              MUF     FS6,2
        26 0 01456              MUF     LOCAT2

01104   27 0 01455              DVF     LOCAT1
        27 2 34001              DVF     FS3,2

01105   20 2 24141              STA     FS2,2
        75 0 01071              SLJ     DIF4

01106   75 0 00000      DVTHM   SLJ     **
        50 4 00000              ENI     0,4

01107   12 4 24141      LOOP7   LDA     FS2,4
        15 4 14301              SUB     FS1,4
```

```
01110   22 4 14301          STA   FS1,4
        50 0 00000

01111   54 4 07600    +     ISK   76008,4
        75 0 01107          SLJ   LOOP7

01112   75 0 01106          SLJ   DVTHM
        50 0 00000

01113   75 0 00000    DTHM  SLJ   **
        50 4 00000          ENI   0,4

01114   12 4 04441    LOOP8 LDA   FS0,4
        26 4 04441          MUF   FS0,4

01115   20 4 04441          STA   FS0,4
        12 4 14301          LDA   FS1,4

01116   26 4 14301          MUF   FS1,4
        14 4 04441          ADD   FS0,4

01117   75 4 04312    +     RTJ   VAB
        00 0 01466          00    SQFRR

01120   22 4 04441    +     STA   FS0,4
        50 0 00000

01121   54 4 07600    +     ISK   76008,4
        75 0 01114          SLJ   LOOP8

01122   75 0 01113          SLJ   DTHM
        50 0 00000

01123   75 0 00000    KAT1  SLJ   **
        50 4 00000          ENI   0,4

01124   12 4 53501    LOOP9 LDA   FS5,4
        15 4 04441          SUB   FS0,4

01125   20 4 53501          STA   FS5,4
        50 0 00000

01126   54 4 07600    +     ISK   76008,4
        75 0 01124          SLJ   LOOP9

01127   75 0 01123          SLJ   KAT1
        50 0 00000

01130   75 0 00000    UGEOS1 SLJ  **
        50 0 00000

01131   75 4 04075    DIF5  RTJ   SAH
        00 0 01134          00    OUTSID5

01132   50 0 01136    +     ENI   INSID5
        50 0 01136          ENI   INSID5

01133   75 0 01130    +     SLJ   UGEOS1
        50 0 00000

01134   10 0 00000    OUTSID5 ENA 0
        20 2 24141          STA   FS2,2

01135   75 0 01131          SLJ   DIF5
        50 0 00000

01136   12 2 43641    INSID5 LDA  FS4,2
        01 0 00001          ARS   1

01137   14 4 01434          ADD   CONST1
        20 0 01455          STA   LOCAT1
```

```
01140   26 0 01455              MUF     LOCAT1
        20 0 01455              STA     LOCAT1

01141   12 3 04441              LDA     FS0,3
        15 1 04441              SUB     FS0,1

01142   20 0 01456              STA     LOCAT2
        12 0 01435              LDA     CONST2

01143   26 2 63341              MUF     FS6,2
        26 0 01456              MUF     LOCAT2

01144   27 0 01455              DVF     LOCAT1
        20 2 24141              STA     FS2,2

01145   75 0 01131              SLJ     DIF5
        50 0 00000

01146   75 0 00000      UGEOS2  SLJ     **
        50 0 00000

01147   75 4 04075      DIF6    RTJ     SAH
        00 0 01152              00      OUTSID6

01150   50 0 01154      +       ENI     INSID6
        50 0 01154              ENI     INSID6

01151   75 0 01146      +       SLJ     UGEOS2
        50 0 00000

01152   10 0 00000      OUTSID6 FNA     0
        20 2 34001              STA     FS3,2

01153   75 0 01147              SLJ     DIF6
        50 0 00000

01154   12 2 43641      INSID6  LDA     FS4,2
        01 0 00001              ARS     1

01155   14 0 01434              ADD     CONST1
        20 0 01455              STA     LOCAT1

01156   26 0 01455              MUF     LOCAT1
        20 0 01455              STA     LOCAT1

01157   12 3 14301              LDA     FS1,3
        15 1 14301              SUB     FS1,1

01160   20 0 01456              STA     LOCAT2
        12 0 01435              LDA     CONST2

01161   26 2 63341              MUF     FS6,2
        26 0 01456              MUF     LOCAT2

01162   27 0 01455              DVF     LOCAT1
        20 2 34001              STA     FS3,2

01163   75 0 01147              SLJ     DIF6
        50 0 00000

01164   75 0 00000      UGEOS   SLJ     **
        50 4 00000              ENI     0,4

01165   12 4 24141      LOOP10  LDA     FS2,4
        05 0 00003              ALS     3

01166   20 0 01455              STA     LOCAT1
        12 4 34001              LDA     FS3,4

01167   05 0 00003              ALS     3
        14 0 01455              ADD     LOCAT1
```

```
01170   20 4 24141          STA     FS2,4
        50 0 00000

01171   54 4 07600    +     ISK     7600B,4
        75 0 01165          SLJ     LOOP10

01172   75 0 01164          SLJ     UGEOS
        50 0 00000

01173   75 0 00000    VGEOS1  SLJ     **
        50 0 00000

01174   75 4 04075    DIF7    RTJ     SAH
        00 0 01177          00      OUTSID7

01175   50 0 01201    +     ENI     INSID7
        50 0 01201          ENI     INSID7

01176   75 0 01173    +     SLJ     VGEOS1
        50 0 00000

01177   10 0 00000    OUTSID7 ENA     0
        20 2 34001          STA     FS3,2

01200   75 0 01174          SLJ     DIF7
        50 0 00000

01201   12 2 43641    INSID7  LDA     FS4,2
        01 0 00001          ARS     1

01202   14 0 01434          ADD     CONST1
        20 0 01455          STA     LOCAT1

01203   26 0 01455          MUF     LOCAT1
        20 0 01455          STA     LOCAT1

01204   12 2 04442          LDA     FS0+1,2
        15 2 04440          SUB     FS0-1,2

01205   20 0 01456          STA     LOCAT2
        12 0 01435          LDA     CONST2

01206   26 2 63341          MUF     FS6,2
        26 0 01456          MUF     LOCAT2

01207   27 0 01455          DVF     LOCAT1
        20 2 34001          STA     FS3,2

01210   75 0 01174          SLJ     DIF7
        50 0 00000

01211   75 0 00000    VGEOS2  SLJ     **
        50 0 00000

01212   75 4 04075    DIF8    RTJ     SAH
        00 0 01215          00      OUTSID8

01213   50 0 01217    +     ENI     INSID8
        50 0 01217          ENI     INSID8

01214   75 0 01211    +     SLJ     VGEOS2
        50 0 00000

01215   10 0 00000    OUTSID8 ENA     0
        20 2 04441          STA     FS0,2

01216   75 0 01212          SLJ     DIF8
        50 0 00000

01217   12 2 43641    INSID8  LDA     FS4,2
        01 0 00001          ARS     1
```

```
01220   14 3 01434          ADD   CONST1
        20 3 01455          STA   LOCAT1

01221   26 3 01455          MUF   LOCAT1
        20 3 01455          STA   LOCAT1

01222   12 2 14302          LDA   FS1+1,2
        15 2 14300          SUB   FS1-1,2

01223   20 0 01456          STA   LOCAT2
        12 0 01435          LDA   CONST2

01224   26 2 63341          MUF   FS6,2
        26 0 01456          MUF   LOCAT2

01225   27 0 01455          DVF   LOCAT1
        20 2 04441          STA   FS0,2

01226   75 0 01212          SLJ   DIF8
        50 0 00000

01227   75 0 00000  VGEOS    SLJ   **
        50 4 00000          ENI   0,4

01230   12 4 34001  LOOP11   LDA   FS3,4
        05 0 00003          ALS   3

01231   20 0 01455          STA   LOCAT1
        12 4 04441          LDA   FS0,4

01232   05 0 00003          ALS   3
        14 0 01455          ADD   LOCAT1

01233   20 4 04441          STA   FS0,4
        50 0 00000

01234   54 4 07600  +        ISK   7600B,4
        75 0 01230          SLJ   LOOP11

01235   75 0 01227          SLJ   VGEOS
        50 0 00000

01236   75 0 00000  KINETIC   SLJ   **
        50 4 00000          ENI   0,4

01237   12 4 24141  LOOP12   LDA   FS2,4
        26 4 24141          MUF   FS2,4

01240   20 0 01455          STA   LOCAT1
        12 4 04441          LDA   FS0,4

01241   26 4 04441          MUF   FS0,4
        20 0 01456          STA   LOCAT2

01242   14 0 01455          ADD   LOCAT1
        01 0 00001          ARS   1

01243   20 4 04441          STA   FS0,4
        50 0 00000

01244   54 4 07600  +        ISK   7600B,4
        75 0 01237          SLJ   LOOP12

01245   75 0 01236          SLJ   KINETIC
        50 0 00000

01246   75 0 00000  KAT2     SLJ   **
        50 4 00000          ENI   0,4

01247   12 4 53501  LOOP13   LDA   FS5,4
        15 4 04441          SUB   FS0,4
```

```
01250   20 4 04441          STA   FS0,4
        50 0 00000

01251   54 4 07600    +     ISK   7600B,4
        75 0 01247          SLJ   LOOP13

01252   75 0 01246          SLJ   KAT2
        50 0 00000

01253   75 0 00000    LAYER2 SLJ  **
        12 0 01446          LDA   COUNT

01254   05 0 00001          ALS   1
        20 0 01446          STA   COUNT

01255   22 3 01253          AJPM  LAYER2
        12 0 01437          LDA   NAME1A

01256   20 0 01436          STA   NAME1
        12 0 01441          LDA   NAME2A

01257   20 0 01440          STA   NAME2
        12 0 01443          LDA   NAME3A

01260   20 0 01442          STA   NAME3
        12 0 01445          LDA   NAME4A

01261   20 0 01444          STA   NAME4
        12 0 01447          LDA   LEVEL2

01262   20 0 01316          STA   TITLE+3
        20 0 01341          STA   TITLE1+3

01263   20 0 01364          STA   TITLE2+3
        20 0 01407          STA   TITLE4+3

01264   20 0 01432          STA   TITLE7+3
        12 0 01450          LDA   A2

01265   20 0 01306          STA   A1
        12 0 01451          LDA   B2

01266   20 0 01307          STA   B1
        12 0 01452          LDA   C2

01267   20 0 01311          STA   C1
        12 0 01453          LDA   D2

01270   20 0 01310          STA   D1
        12 0 01454          LDA   E2

01271   61 0 01305          SAL   E1
        12 0 01457          LDA   TAPUNIT

01272   61 0 00664          SAL   HIGHD
        61 0 00712          SAL   HIGHT

01273   75 0 00601          SLJ   START
        50 0 00000

01274   75 0 00000    PRINT SLJ   **
        10 0 77777          ENA   77777B

01275   20 0 00017          STA   17B
        50 0 00000

01276   75 0 01302    +     SLJ   *+4
        00 0 00000          00    0

01277   00 0 14301          00    FS1
        00 0 63141          00    FS6
```

```
01300   00 0 00047              00    39
        00 0 00035              00    29

01301   00 0 00022              00    18
        00 0 00010              00    8

01302   75 4 04371      +       RTJ   WAE
        00 0 00000              00    0

01303   75 4 02202      +       RTJ   MAC
        00 0 63341              00    FS6,0

01304   75 0 01274      +       SLJ   PRINT
        77 7 63341              77    FS6,7

01305   00 0 01460      F1      00    TAU
        00 0 00004              00    4

01306   13 1 11710      A1      OCT   1311171047640243
        47 6 40243

01307   02 4 76132      B1      OCT   0247613261070664
        61 0 70664

01310   00 1 42600      D1      OCT   0014260000000000
        00 0 00000

01311   01 3 56000      C1      OCT   0135600000000000
        00 0 00000

01312   00 0 00026              00    22
        00 0 00026              00    22

01313   20 4 34626      TITLE   BCD   4, LOWER LEVEL Z FIELD    LAYER 1
        65 5 12043

01314   65 2 56543      TITLE   BCD   4, LOWER LEVEL Z FIELD    LAYER 1
        20 3 12966

01315   71 6 54364      TITLE   BCD   4, LOWER LEVEL Z FIELD    LAYER 1
        20 2 02020

01316   43 6 13065      TITLE   BCD   4, LOWER LEVEL Z FIELD    LAYER 1
        51 2 00120

01317   75 0 01274              SLJ   PRINT
        50 0 00000

01320   75 0 00000      PRINT1  SLJ   **
        50 0 00000

01321   75 0 01325      +       SLJ   *+4
        00 0 00000              00    0

01322   00 0 53501              00    FS5
        00 0 63341              00    FS6

01323   00 0 00047              00    39
        00 0 00035              00    29

01324   00 0 00022              00    18
        00 0 00010              00    8

01325   75 4 04371      +       RTJ   WAE
        00 0 00000              00    0

01326   75 4 02202      +       RTJ   MAC
        00 0 63341              00    FS6,0

01327   75 0 01320              SLJ   PRINT1
        77 7 63341              77    FS6,7
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01330   00 1 01460              DD      TAU
        00 1 00001              DD      1

01331   00 0 00000              OCT     0
        00 0 00000

01332   20 1 03000              DEC     50-1B47
        00 0 00000

01333   00 1 00000              OCT     0
        00 0 00000

01334   04 6 31463              DEC     150-2847
        14 6 31463

01335   00 1 00026              DD      22
        00 0 00026              DD      22

01336   20 1 36147  TITLE1      BCD     4, LAPLACIAN OF VORTICITY LAYER 1
        43 6 16371

01337   61 4 52046  TITLE1      BCD     4, LAPLACIAN OF VORTICITY LAYER 1
        66 2 02546

01340   51 2 37163  TITLE1      BCD     4, LAPLACIAN OF VORTICITY LAYER 1
        71 2 33020

01341   43 6 13165  TITLE1      BCD     4, LAPLACIAN OF VORTICITY LAYER 1
        51 2 00120

01342   75 1 01320              SLJ     PRINT1
        50 1 00000

01343   75 1 00000  PRINT2      SLJ     **
        50 1 00000

01344   75 0 01350  +           SLJ     *+4
        00 1 00100              DD      0

01345   00 0 04441              DD      FS0
        00 1 63341              DD      FS6

01346   00 0 00047              DD      39
        00 0 00035              DD      29

01347   00 1 00022              DD      18
        00 1 00010              DD      8

01350   75 4 04371  SKIP        RTJ     WAE
        00 0 00000              DD      0

01351   75 4 02202  +           RTJ     MAC
        00 4 63341              DD      FS6,0

01352   75 1 01343              SLJ     PRINT2
        77 7 63341              DD      FS6,7

01353   00 0 01460              DD      TAU
        00 0 00001              DD      1

01354   00 0 00000              OCT     0
        00 0 00000

01355   20 1 00000              DEC     50-1B47
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01357   00 6 31463              DEC     250-3847
        14 6 31463
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        00 0 00026              00    22

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        23 2 06751

01362   61 6 42046    TITLE2    BCD   4, VERT GRAD OF VT        LAYER 1
        6F 2 02523

01363   20 2 02020    TITLE2    BCD   4, VERT GRAD OF VT        LAYER 1
        20 2 02020

01364   43 6 13065    TITLE2    BCD   4, VERT GRAD OF VT        LAYER 1
        51 2 00120

01365   75 0 01343              SLJ   PRINT2
        50 0 00000

01366   75 0 00000    PRINT1    SLJ   **
        50 0 00000

01367   75 0 01373    +         SLJ   **+4
        00 0 00000              00    0

01370   00 0 04441              00    FS0
        00 0 63341              00    FS6

01371   00 0 00047              00    39
        00 0 00035              00    29

01372   00 0 00022              00    18
        00 0 00010              00    8

01373   75 4 04371    +         RTJ   WAE
        00 0 00000              00    0

01374   75 4 02202    +         RTJ   MAC
        00 0 63341              00    FS6,0

01375   75 0 01466              SLJ   PRINT3
        77 7 63341              77    FS6,7

01376   00 0 01460              00    TAU
        00 0 00001              00    1

01377   00 0 00000              OCT   0
        00 0 00000

01400   20 0 00000              DEC   5D-1B47
        00 0 00000

01401   00 0 00000              OCT   0
        00 0 00000

01402   01 4 63146              DEC   5D-2B47
        31 4 63146

01403   00 0 00026              00    22
        00 0 00026              00    22

01404   20 4 27145    TITLE4    BCD   4, KINETIC ENERGY         LAYER 1
        65 2 37163

01405   20 6 54565    TITLE4    BCD   4, KINETIC ENERGY         LAYER 1
        51 6 73020

01406   20 2 02020    TITLE4    BCD   4, KINETIC ENERGY         LAYER 1
        20 2 02020

01407   43 6 13065    TITLE4    BCD   4, KINETIC ENERGY         LAYER 1
        51 2 00120
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01410   75 0 01366                      SLJ     PRINT3
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01411   75 0 00000          PRINT4      SLJ     **
        50 0 00000

01412   75 0 01416          +           SLJ     **+4
        00 0 00000                      00      0

01413   00 0 04441                      00      FS0
        00 0 63341                      00      FS6

01414   00 0 00047                      00      39
        00 0 00035                      00      29

01415   00 0 00022                      00      18
        00 0 00010                      00      8

01416   75 4 04371          +           RTJ     WAE
        00 0 00000                      00      0

01417   75 4 02202          +           RTJ     MAC
        00 1 63341                      00      FS6,0

01420   75 0 01411                      SLJ     PRINT4
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01421   00 0 01460                      00      TAU
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01422   00 0 00000                      OCT     0
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01423   20 0 00000                      DEC     5D-1B47
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01425   03 1 46314                      DEC     1D-1B47
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01426   00 0 00026                      00      22
        00 0 00026                      00      22

01427   20 4 75146          TITLE7      BCD     4, PROG KAT FIELD       LAYER 1
        57 2 04261

01430   23 2 06671          TITLE7      BCD     4, PROG KAT FIELD       LAYER 1
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01431   20 2 02020          TITLE7      BCD     4, PROG KAT FIELD       LAYER 1
        20 2 02020

01432   43 6 13065          TITLE7      BCD     4, PROG KAT FIELD       LAYER 1
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01433   75 0 01411                      SLJ     PRINT4
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01434   20 0 00000          CONST1      DEC     5D-1B47
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01435   05 5 11512          CONST2      DEC     17637D-5B47
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01436   64 2 02003          NAME1       OCT     6420200312122020
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01437   64 2 02002          NAME1A      OCT     6420200212122020
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| 01442 | 23 2 02003<br>12 1 22020 | NAME3 | OCT | 2320200312122020 |
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| 01447 | 43 5 13065<br>51 5 00220 | LEVEL2 | OCT | 4361306551200220 |
| 01450 | 07 4 47764<br>15 4 14743 | A2 | OCT | 0724776415014743 |
| 01451 | 01 3 30675<br>72 4 26573 | B2 | OCT | 0103067572026573 |
| 01452 | 02 7 34000<br>00 0 00000 | C2 | OCT | 0273400000000000 |
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| 01456 | 01457 | LOCAT2 | BSS | 1 |
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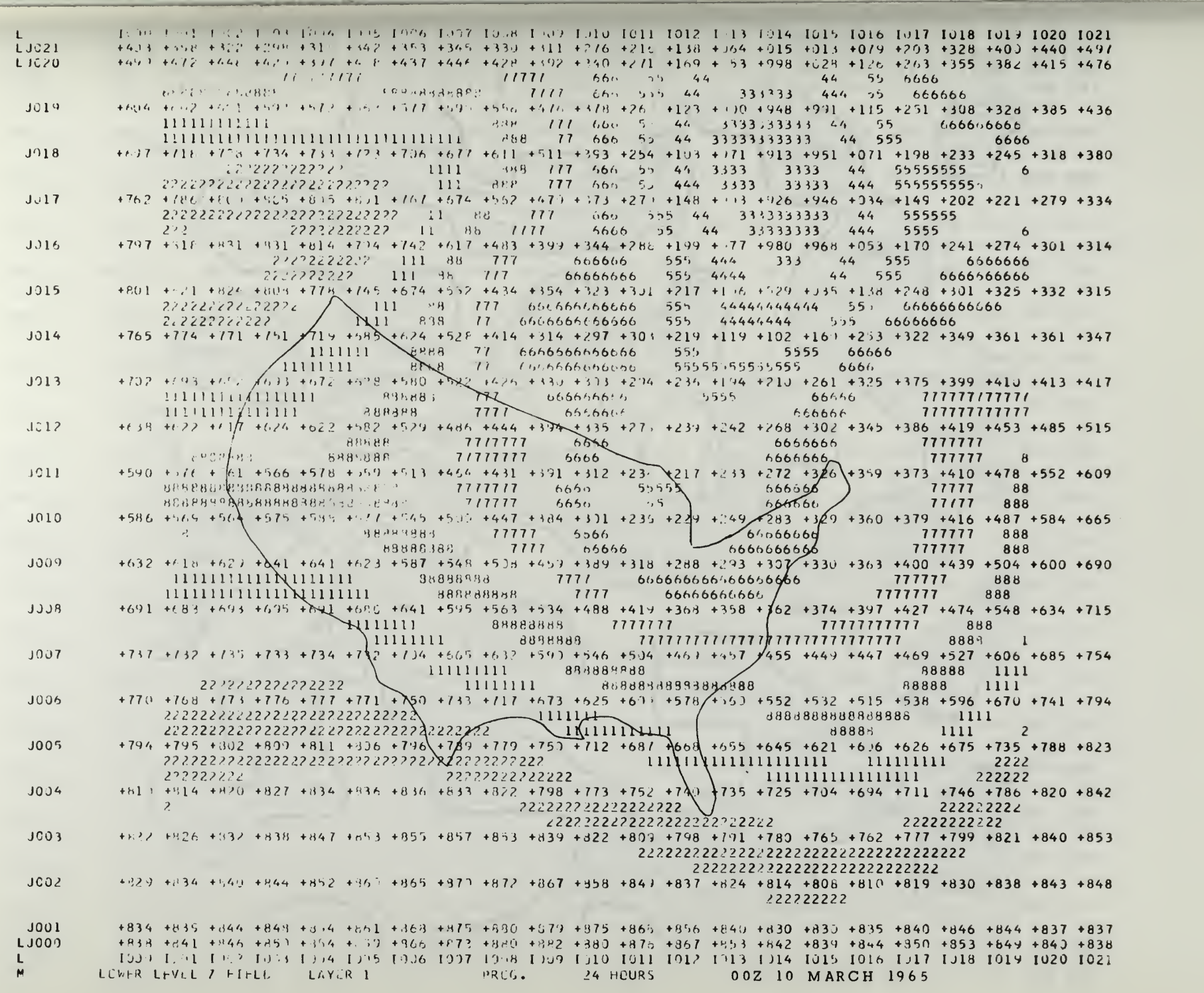
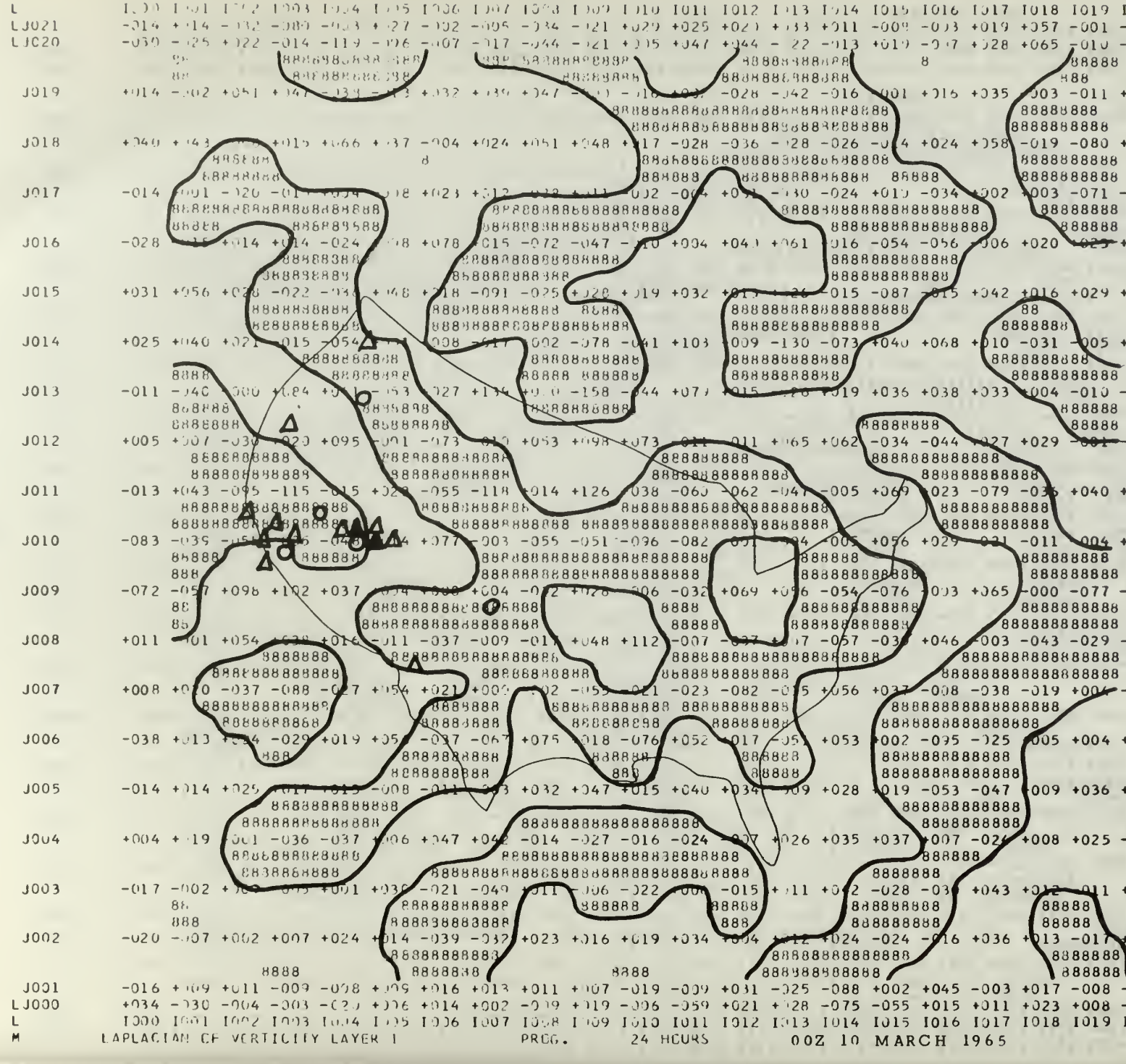
| 01460 | 00 0 00000<br>00 0 00030 | TAU | DEC | 24 |
| 01461 | 12 1 21205<br>12 1 10505 | TIME | OCT | 1212120512010605 |
| 01462 | 76 0 01003<br>50 0 00000 | HATERR | SLS | HHAT |
| 01463 | 76 0 00762<br>50 0 00000 | LAPERR1 | SLS | LAPLAC1 |
| 01464 | 76 0 00770<br>50 0 00000 | LAPERR2 | SLS | LAPLAC2 |
| 01465 | 76 0 00661<br>50 0 00000 | READERR | SLS | READD1 |
| 01466 | 76 0 01113<br>50 0 00000 | SOERR | SLS | DTHM |
| 01467 | 76 0 00750<br>50 0 00000 | VORTER1 | SLS | VORTIS1 |

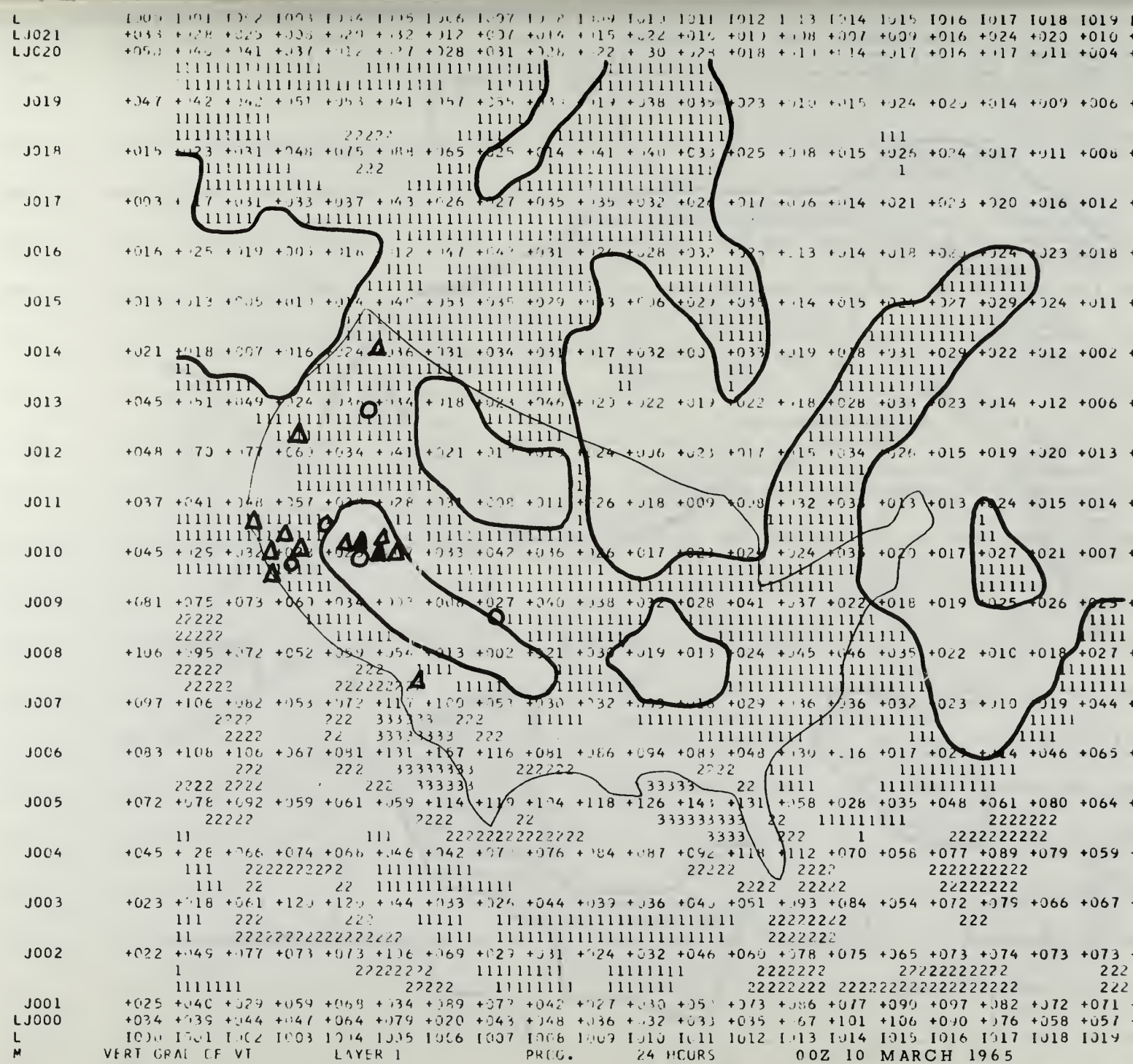
| | | | | |
|---|---|---|---|---|
| 01470 | 76 0 00755<br>50 0 00000 | VORTER2 | SLS | VORTIS2 |
| 01471 | 76 0 00735<br>50 0 00000 | WINDERR | SLS | REWIND |
| 01472 | 02202 | MAA | LIB | MAA |
| 02202 | 03707 | MAC | LIB | MAC |
| 03707 | 04047 | MAG | LIB | MAG |
| 04047 | 04075 | SAD | LIB | SAD |
| 04075 | 04161 | SAH | LIB | SAH |
| 04161 | 04214 | SAI | LIB | SAI |
| 04214 | 04235 | SAJ | LIB | SAJ |
| 04235 | 04312 | SAR | LIB | SAR |
| 04312 | 04341 | VAB | LIB | VAB |
| 04341 | 04371 | WAB | LIB | WAB |
| 04371 | 04441 | WAE | LIB | WAE |
| 04441 | 14301 | FS0 | BSS | 4000 |
| 14301 | 24141 | FS1 | BSS | 4000 |
| 24141 | 34001 | FS2 | BSS | 4000 |
| 34001 | 43641 | FS3 | BSS | 4000 |
| 43641 | 53501 | FS4 | BSS | 4000 |
| 53501 | 63341 | FS5 | BSS | 4000 |
| 63341 | 73201 | FS6 | BSS | 4000 |
| 73201 | 00000 | | END | |

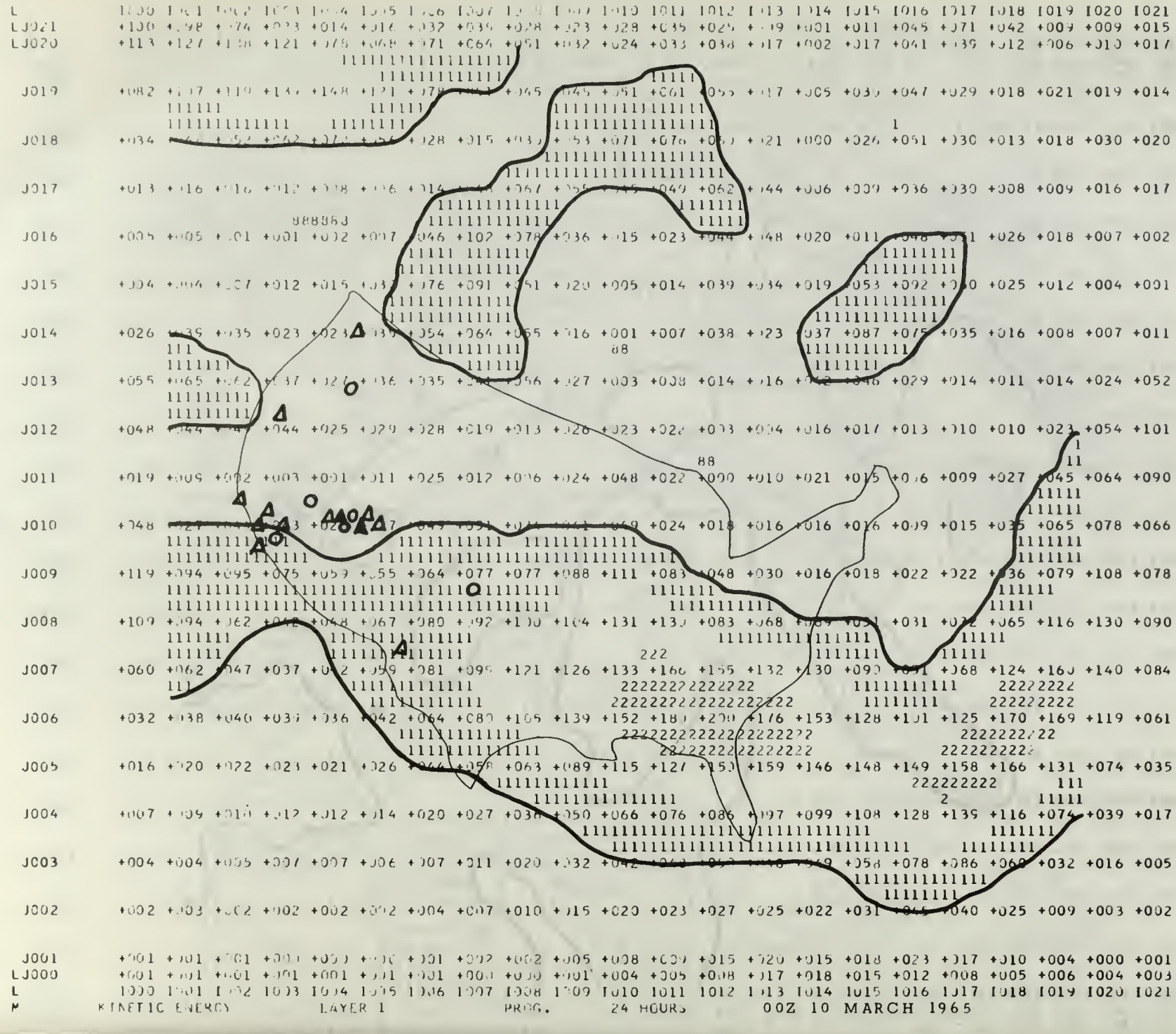
# 10. APPENDIX E

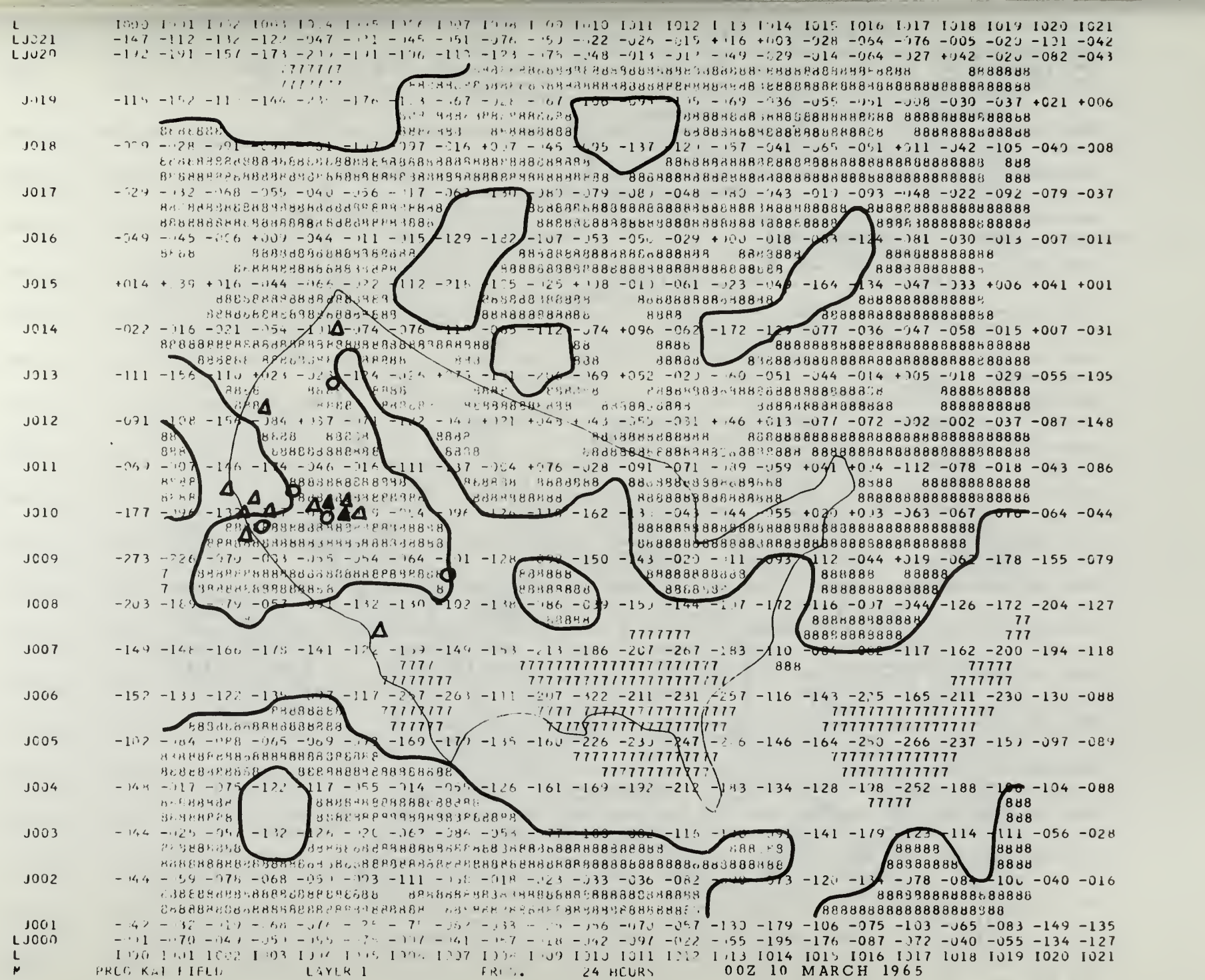
## PRINTED FIELDS FROM THE CLEAR AIR TURBULENCE FORECAST COMPUTER PROGRAM FOR 00Z 10 MARCH 65 THROUGH 12Z 13 MARCH 65

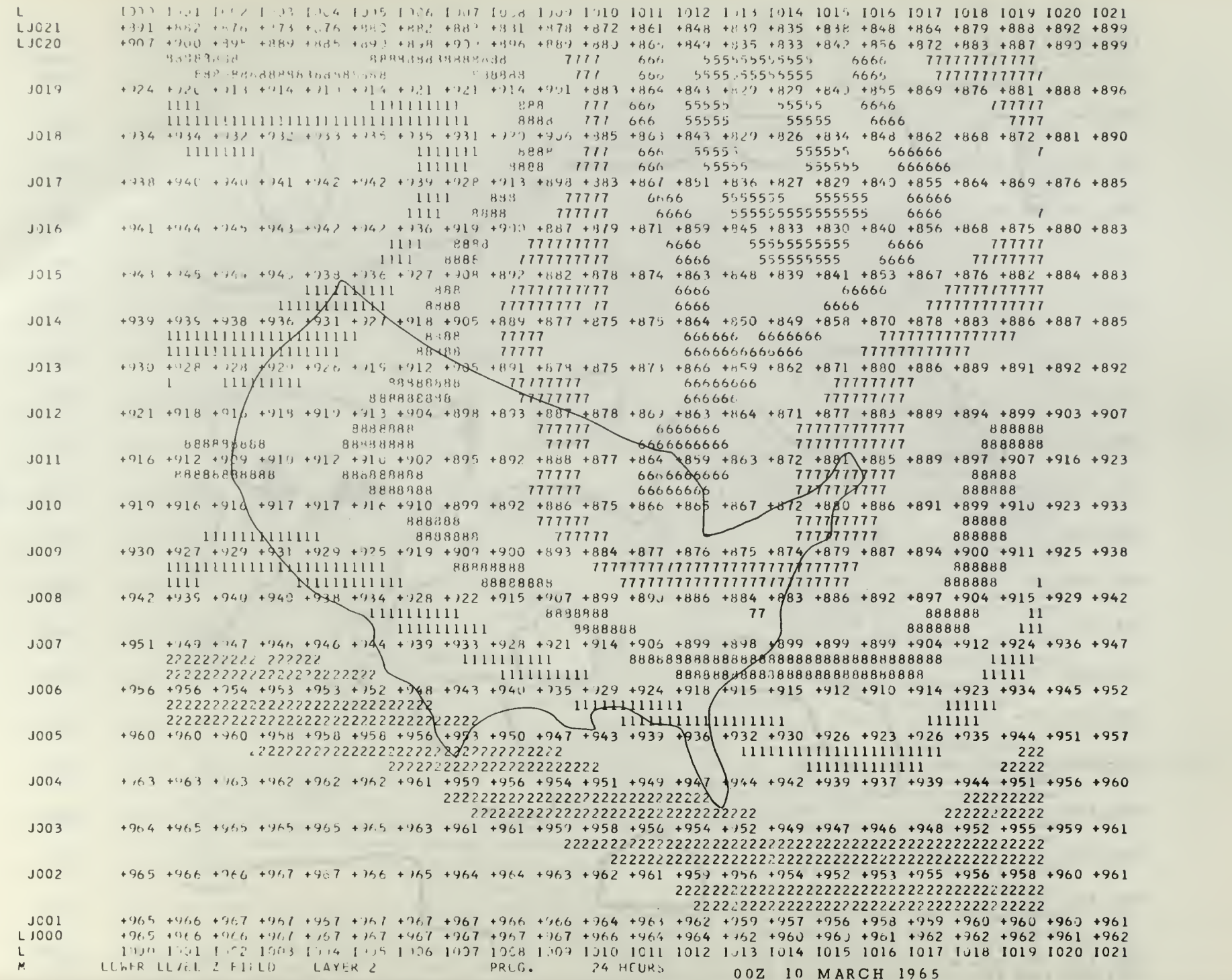

LOWER LEVEL 7 FIELD LAYER 1 PROG. 24 HOURS 00Z 10 MARCH 1965

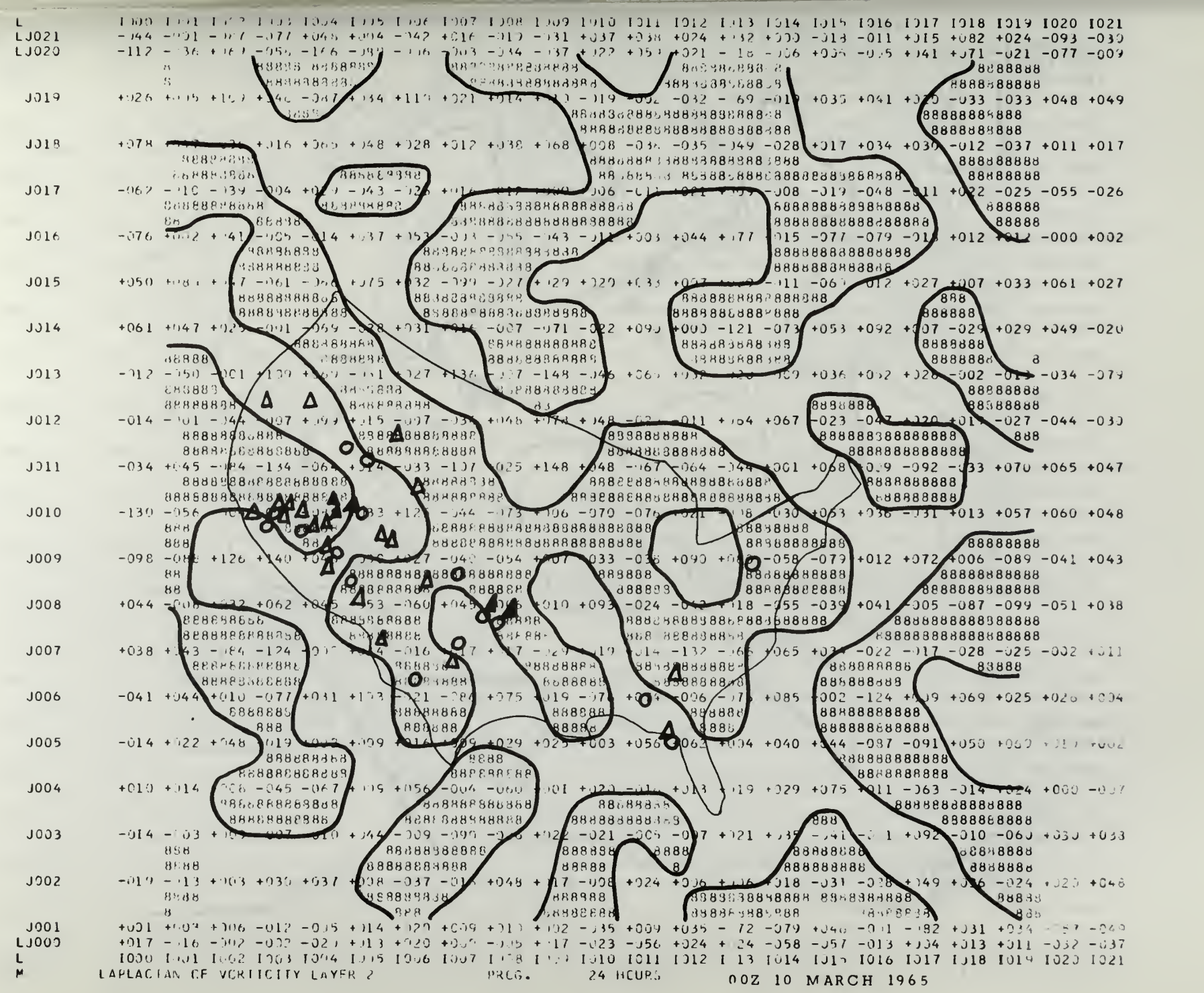

LAPLACIAN OF VERTICITY LAYER 1
PROG. 24 HOURS
00Z 10 MARCH 1965


VERT GRAD OF VT
LAYER 1
PROG.
24 HOURS
00Z 10 MARCH 1965


KINETIC ENERGY LAYER 1 PROG. 24 HOURS 00Z 10 MARCH 1965


PROG KAI FIELD LAYER 1 FROG. 24 HOURS 00Z 10 MARCH 1965


LOWER LEVEL Z FIELD LAYER 2 PROG. 24 HOURS
00Z 10 MARCH 1965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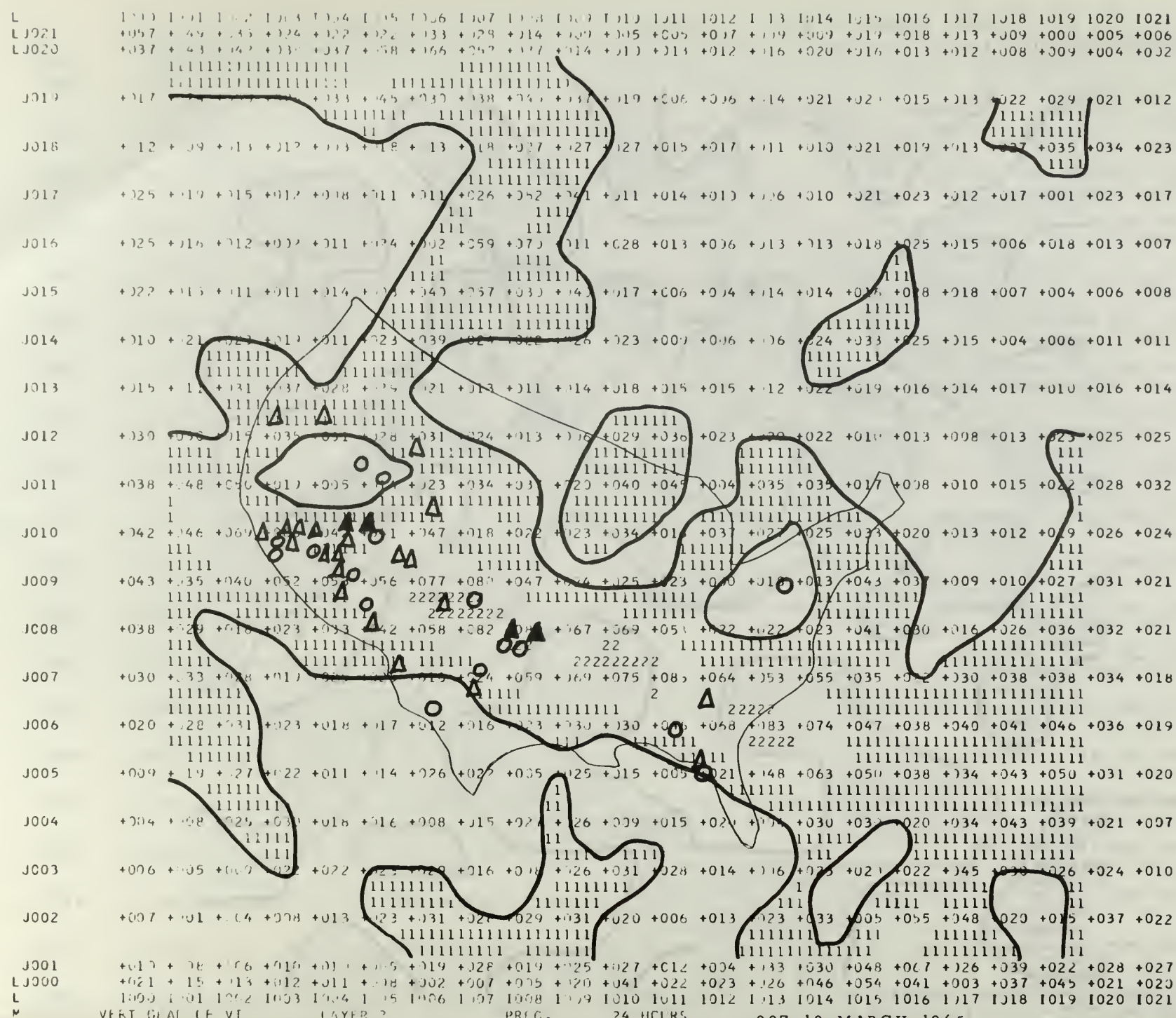
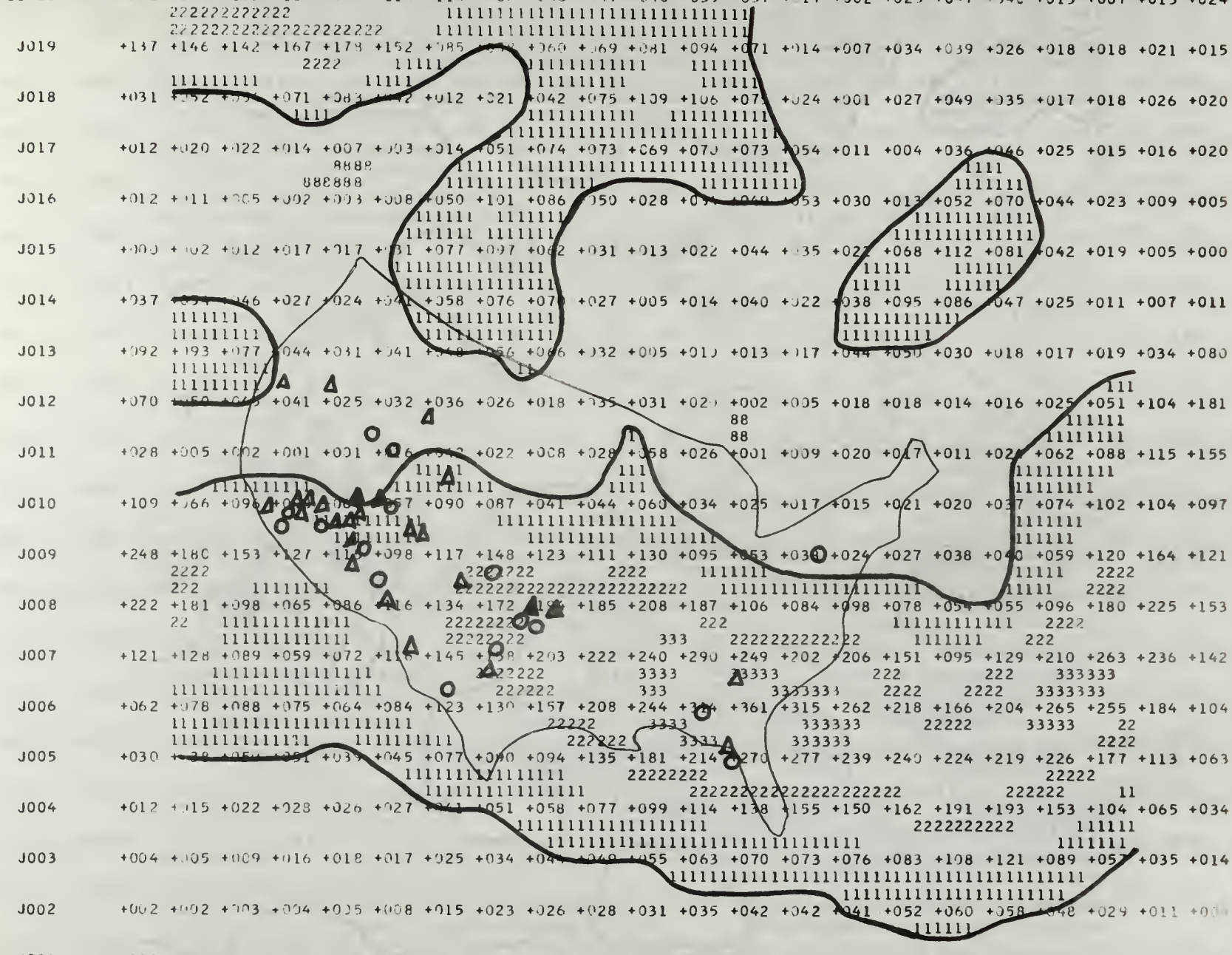
LAPLACIAN OF VORTICITY LAYER 2
PROG. 24 HOURS
00Z 10 MARCH 1965


VERT GRAD OF VT
LAYER 2
PROG.
24 HOURS
00Z 10 MARCH 1965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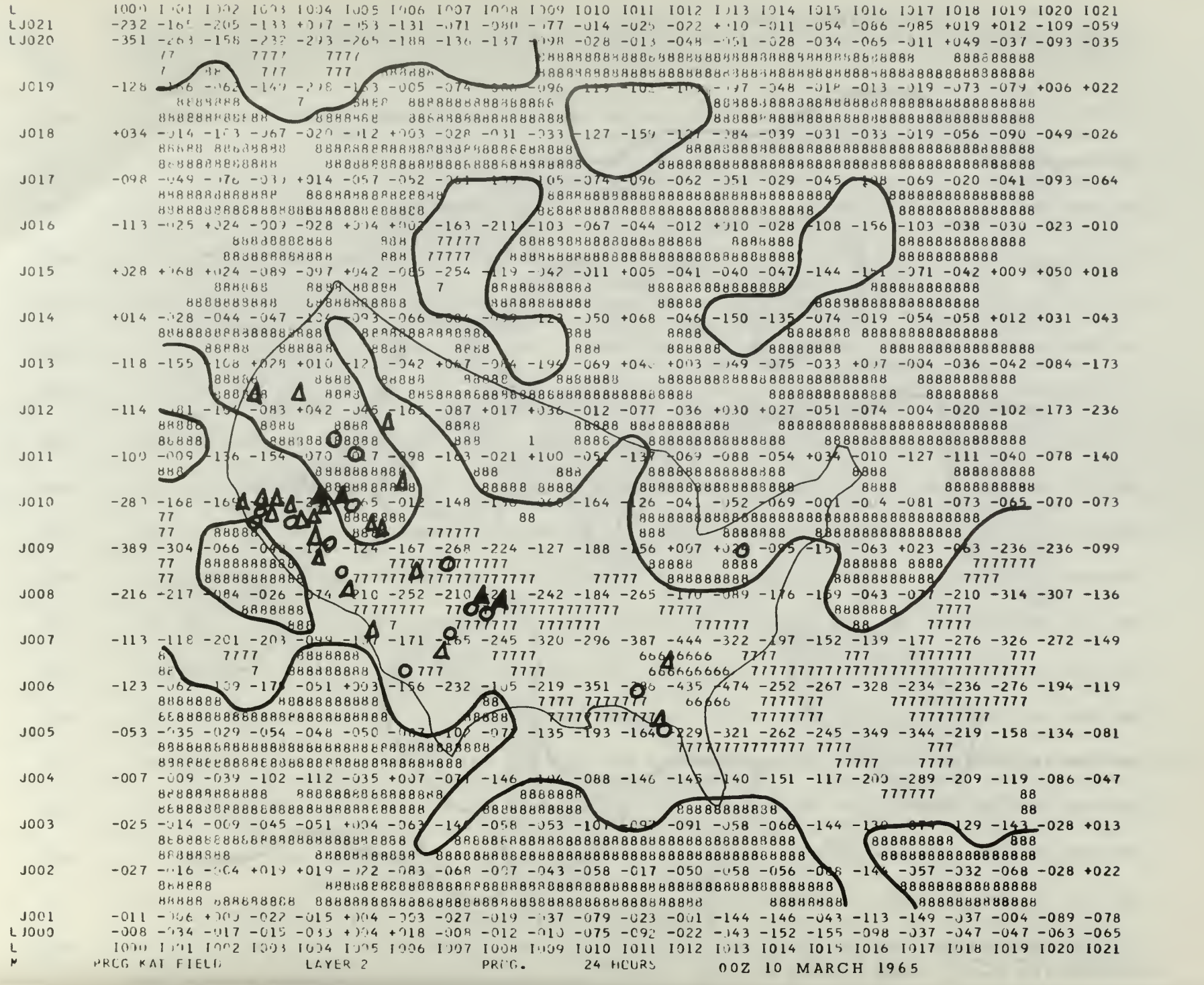
J015
J014
J013
J012
J011
J010
J009
J008
J007
J006
J005
J004
J003
J002
J001
LJ000
I000 I001 I002 I003 I004 I005 I006 I007 I008 I009 I010 I011 I012 I013 I014 I015 I016 I017 I018 I019 I020 I021
KINETIC ENERGY LAYER 2 PROG. 24 HOURS 00Z 10 MARCH 1965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J020 -351 -263 -158 -232 -293 -265 -188 -136 -137 -098 -028 -013 -048 -051 -028 -034 -065 -011 +049 -037 -093 -035
J019 -128 -136 -062 -149 -208 -163 -005 -074 -080 -096 -119 -102 -100 -097 -048 -018 -013 -019 -073 -079 +006 +022
J018 +034 -014 -153 -067 -020 -012 +003 -028 -031 -033 -127 -159 -121 -084 -039 -031 -033 -019 -056 -090 -049 -026
J017 -098 -049 -076 -031 +014 -057 -052 -041 -149 -105 -074 -096 -062 -051 -029 -045 -108 -069 -020 -041 -093 -064
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J007 -113 -118 -201 -203 -099 -[illegible] -171 -265 -245 -320 -296 -387 -444 -322 -197 -152 -139 -177 -276 -326 -272 -149
J006 -123 -062 -139 -176 -051 +003 -156 -232 -105 -219 -351 -[illegible] -435 -474 -252 -267 -328 -234 -236 -276 -194 -119
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J003 -025 -014 -009 -045 -051 +004 -063 -[illegible] -058 -053 -101 -[illegible] -091 -058 -066 -144 -[illegible] -[illegible] -129 -143 -028 +013
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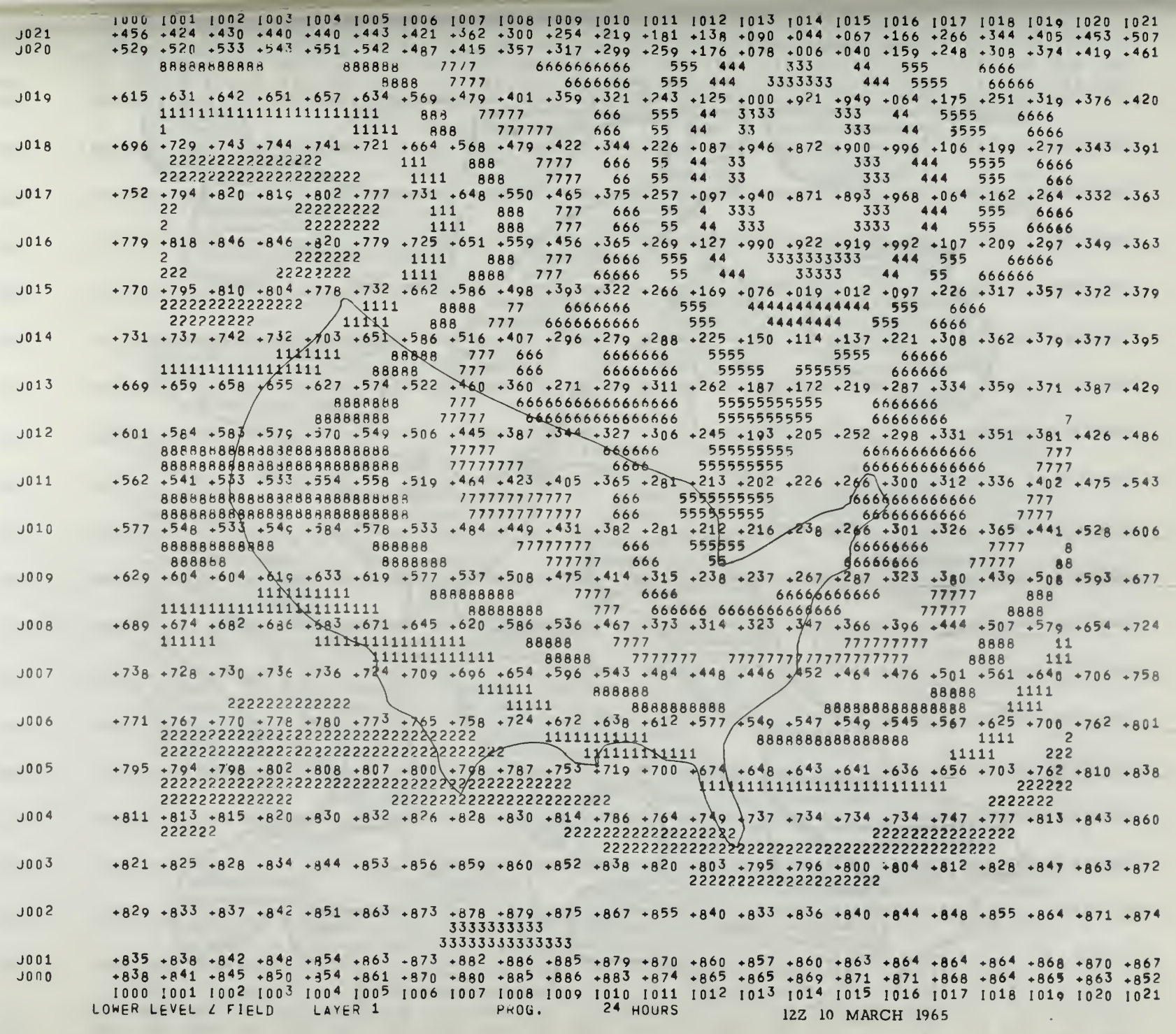
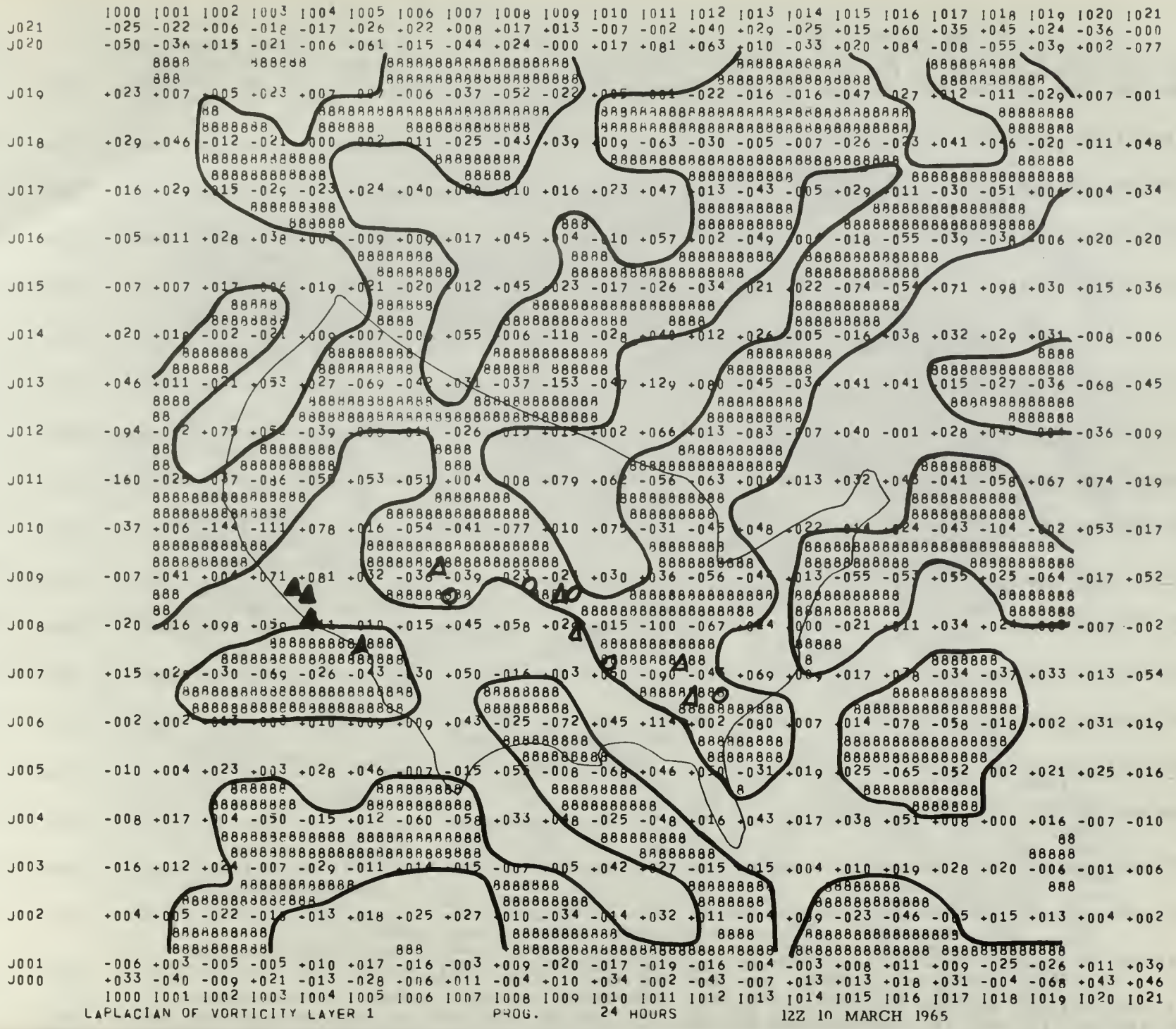
PROG KAT FIELD LAYER 2 PROG. 24 HOURS 00Z 10 MARCH 1965


LOWER LEVEL Z FIELD LAYER 1 PROG. 24 HOURS 12Z 10 MARCH 1965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J017 -016 +029 +015 -029 -023 +024 +040 +000 -010 +016 +023 +047 +013 -043 -005 +029 +011 -030 -051 +004 +004 -034
J016 -005 +011 +028 +038 +007 -009 +009 +017 +045 +004 -010 +057 +002 -049 -001 -018 -055 -039 -038 +006 +020 -020
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J006 -002 +002 -043 -003 +010 +009 +009 +043 -025 -072 +045 +114 +002 -080 +007 +014 -078 -058 -018 +002 +031 +019
J005 -010 +004 +023 +003 +028 +046 -007 -015 +053 -008 -068 +046 +050 -031 +019 +025 -065 -052 +002 +021 +025 +016
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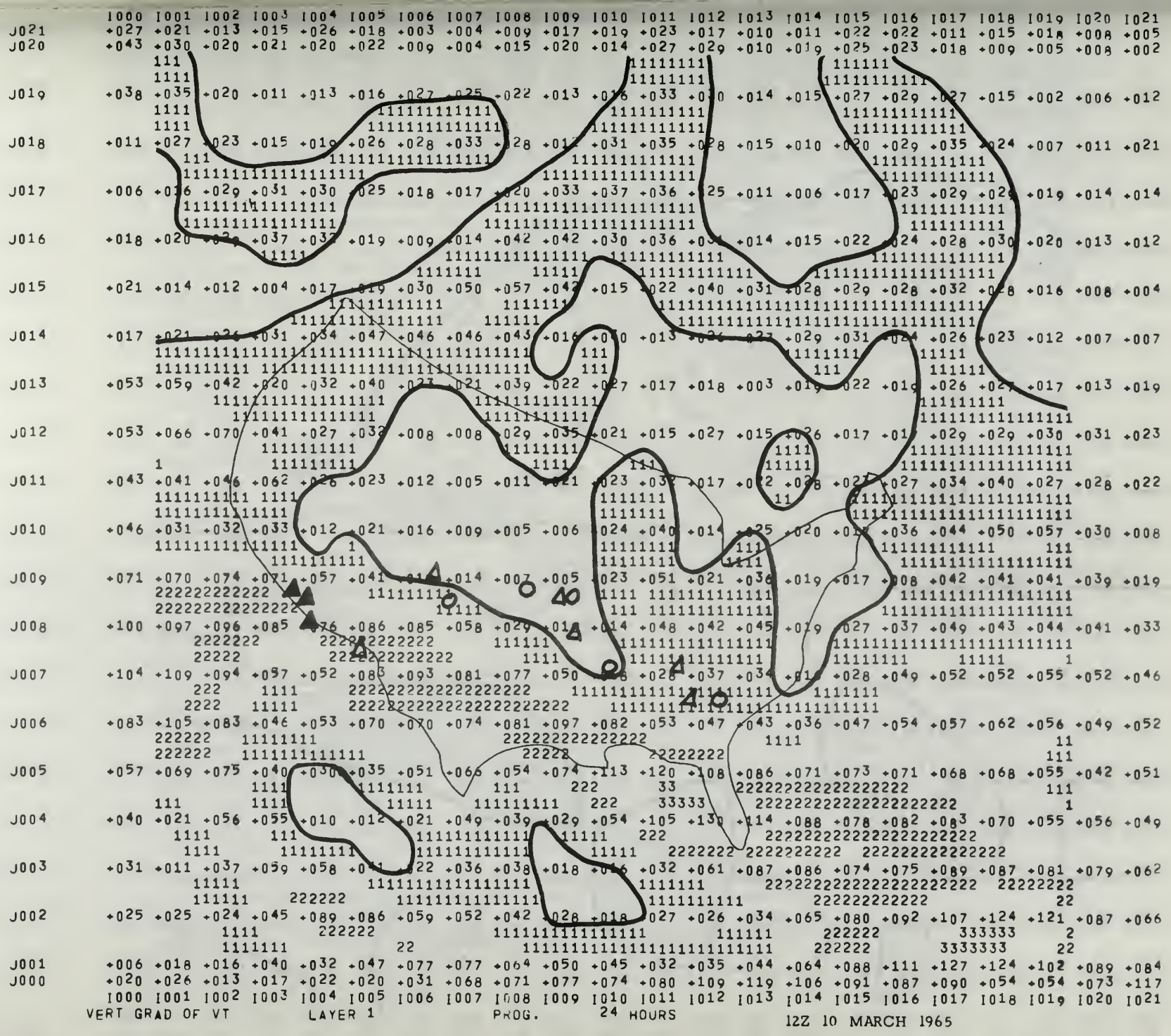
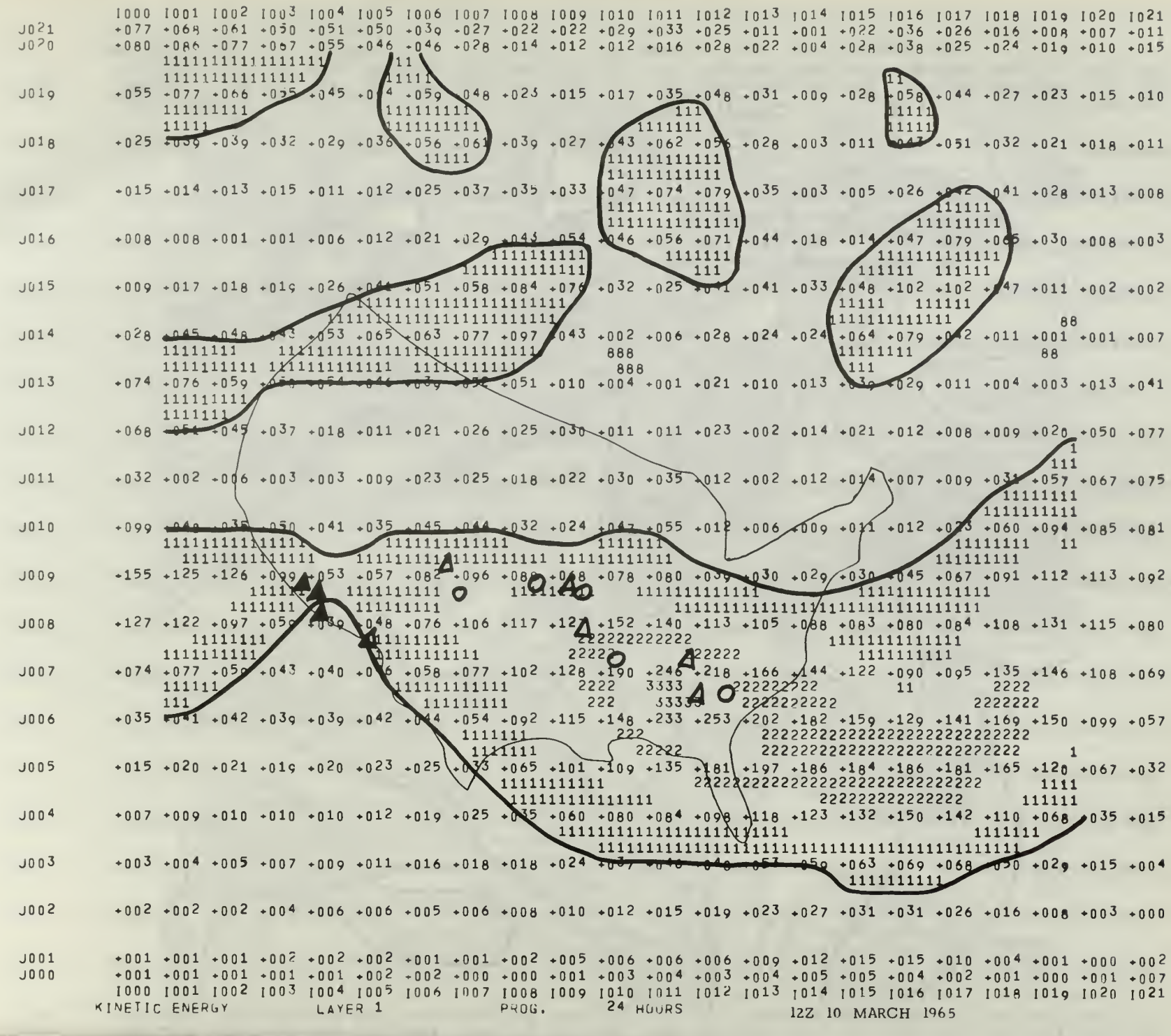
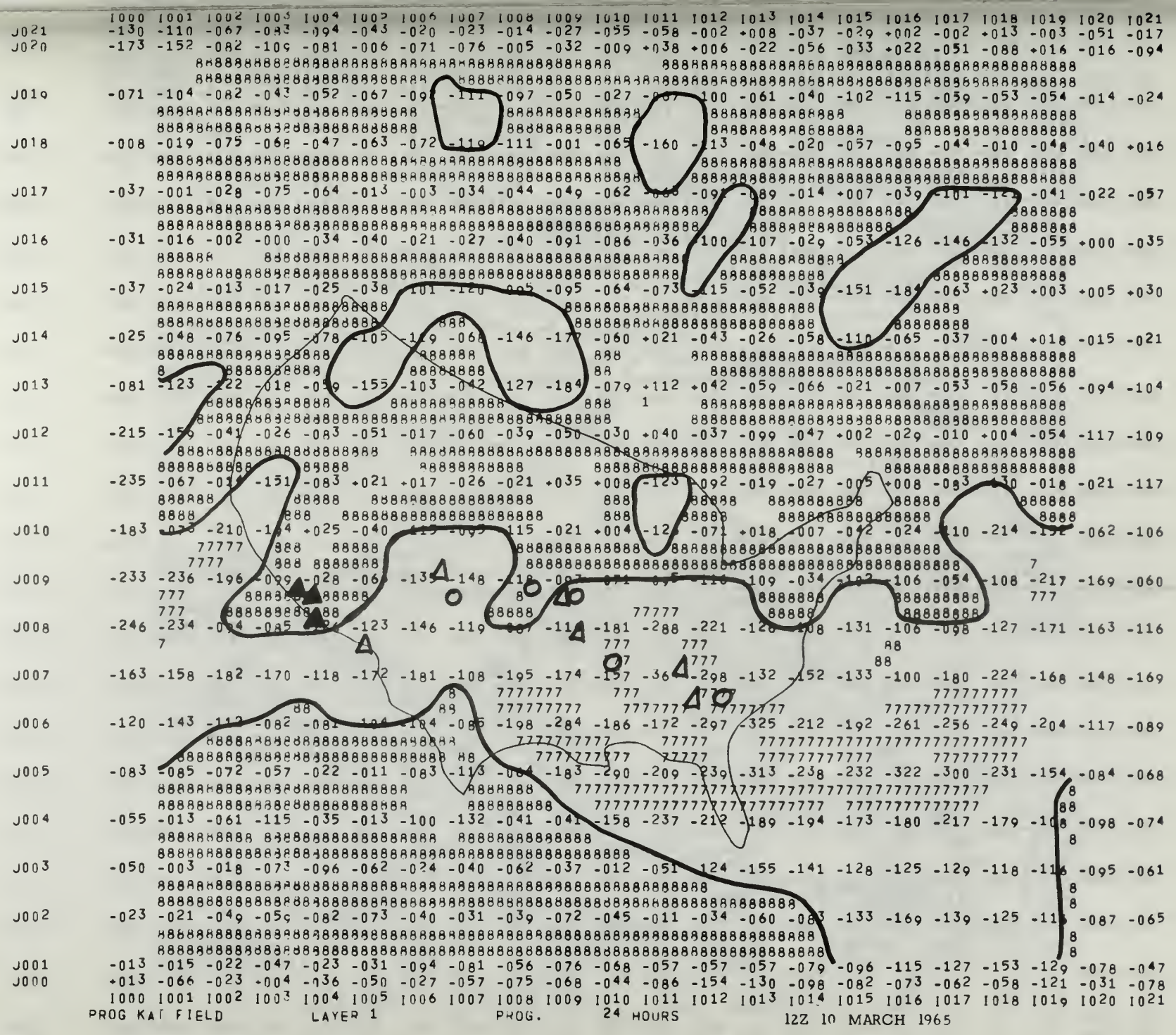
LAPLACIAN OF VORTICITY LAYER 1
PROG. 24 HOURS
12Z 10 MARCH 1965


VERT GRAD OF VT
LAYER 1
PROG.
24 HOURS
12Z 10 MARCH 1965


KINETIC ENERGY LAYER 1 PROG. 24 HOURS 12Z 10 MARCH 1965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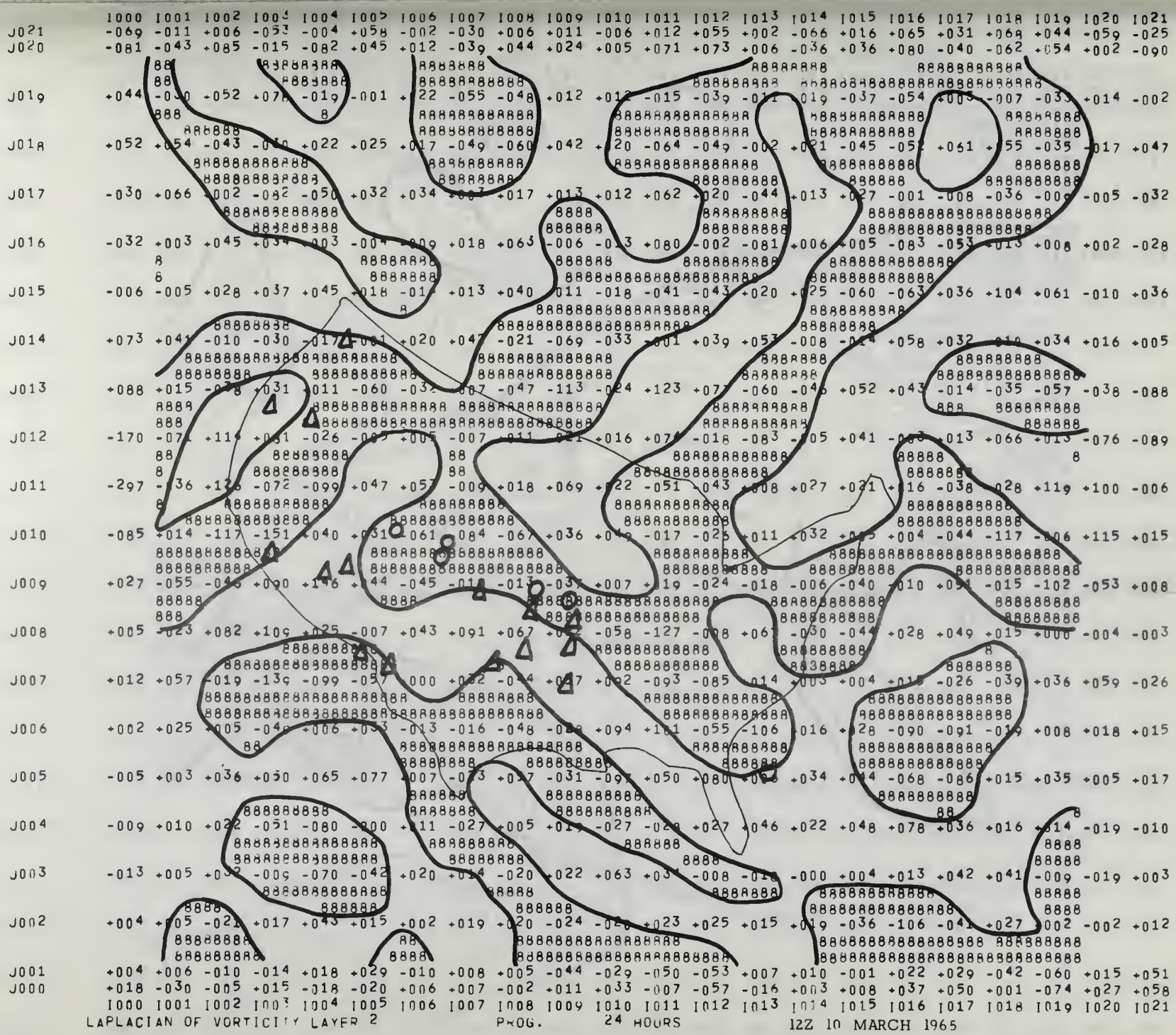
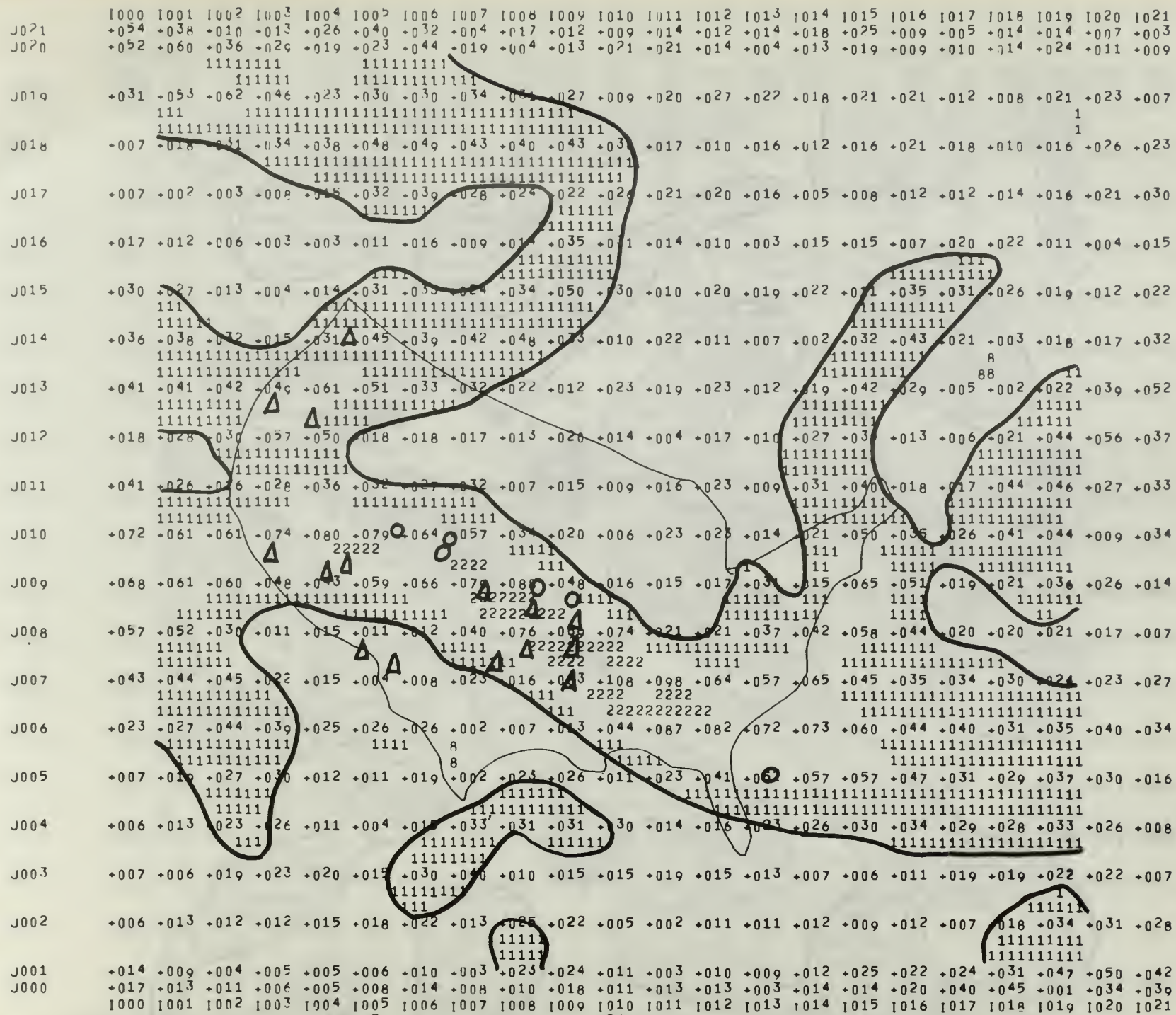
PROG KAT FIELD LAYER 1 PROG. 24 HOURS 12Z 10 MARCH 1965


LOWER LEVEL Z FIELD LAYER 2
PROG. 24 HOURS
12Z 10 MARCH 1965




LAPLACIAN OF VORTICITY LAYER 2 PROG. 24 HOURS 12Z 10 MARCH 1965


VERT GRAD OF VT
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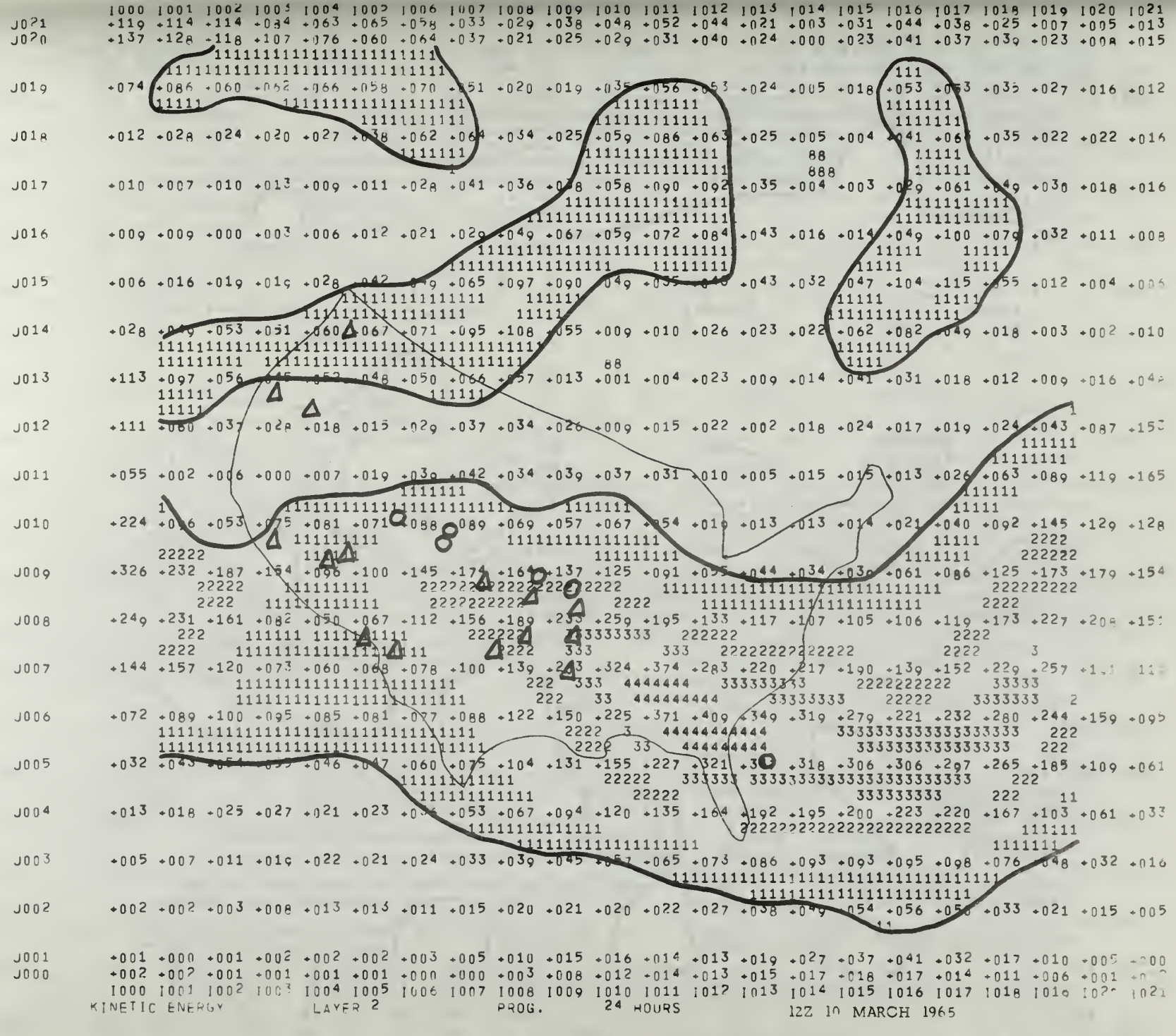
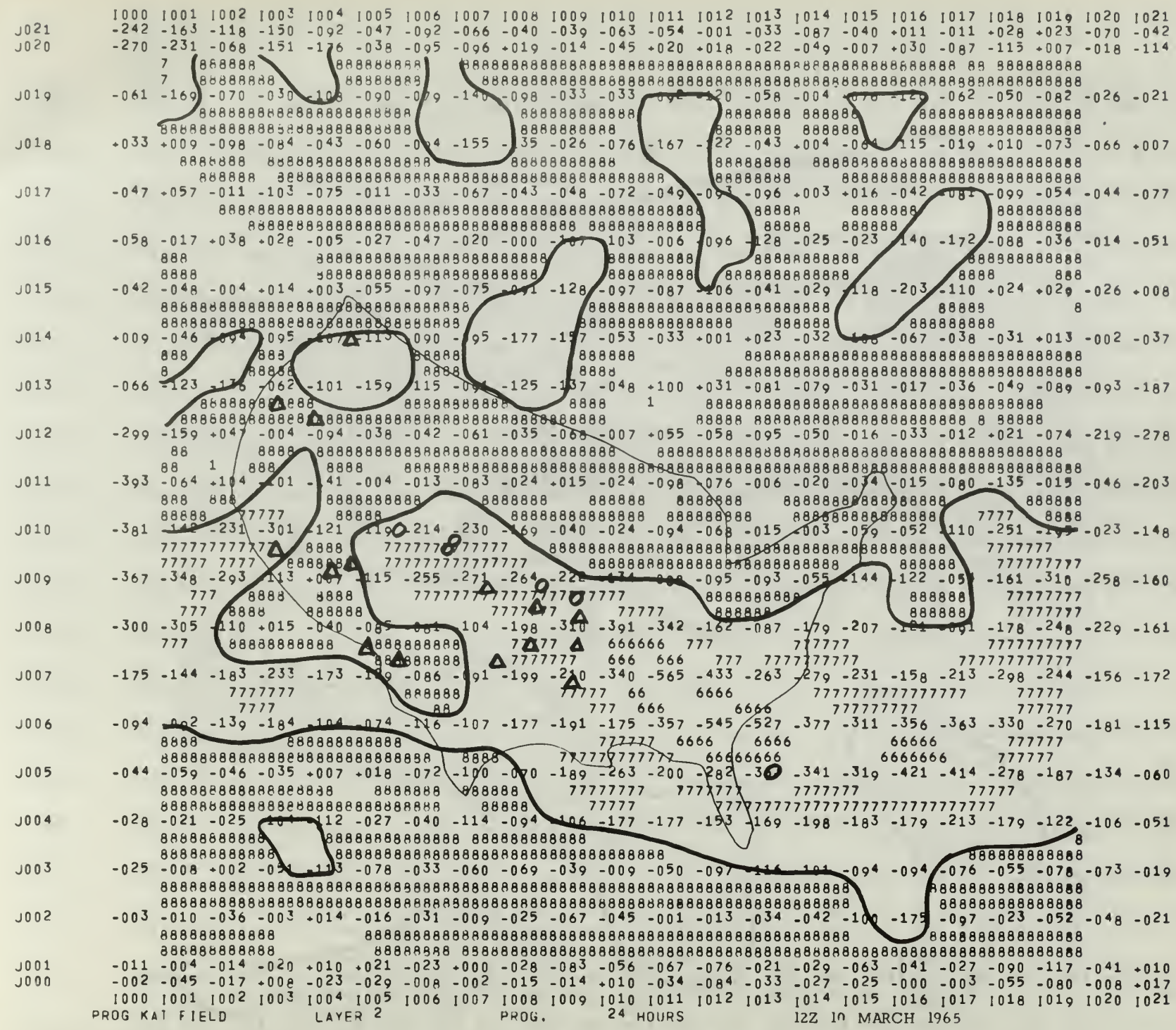
PROG.
24 HOURS
12Z 10 MARCH 1965


KINETIC ENERGY
LAYER 2
PROG.
24 HOURS
12Z 10 MARCH 1965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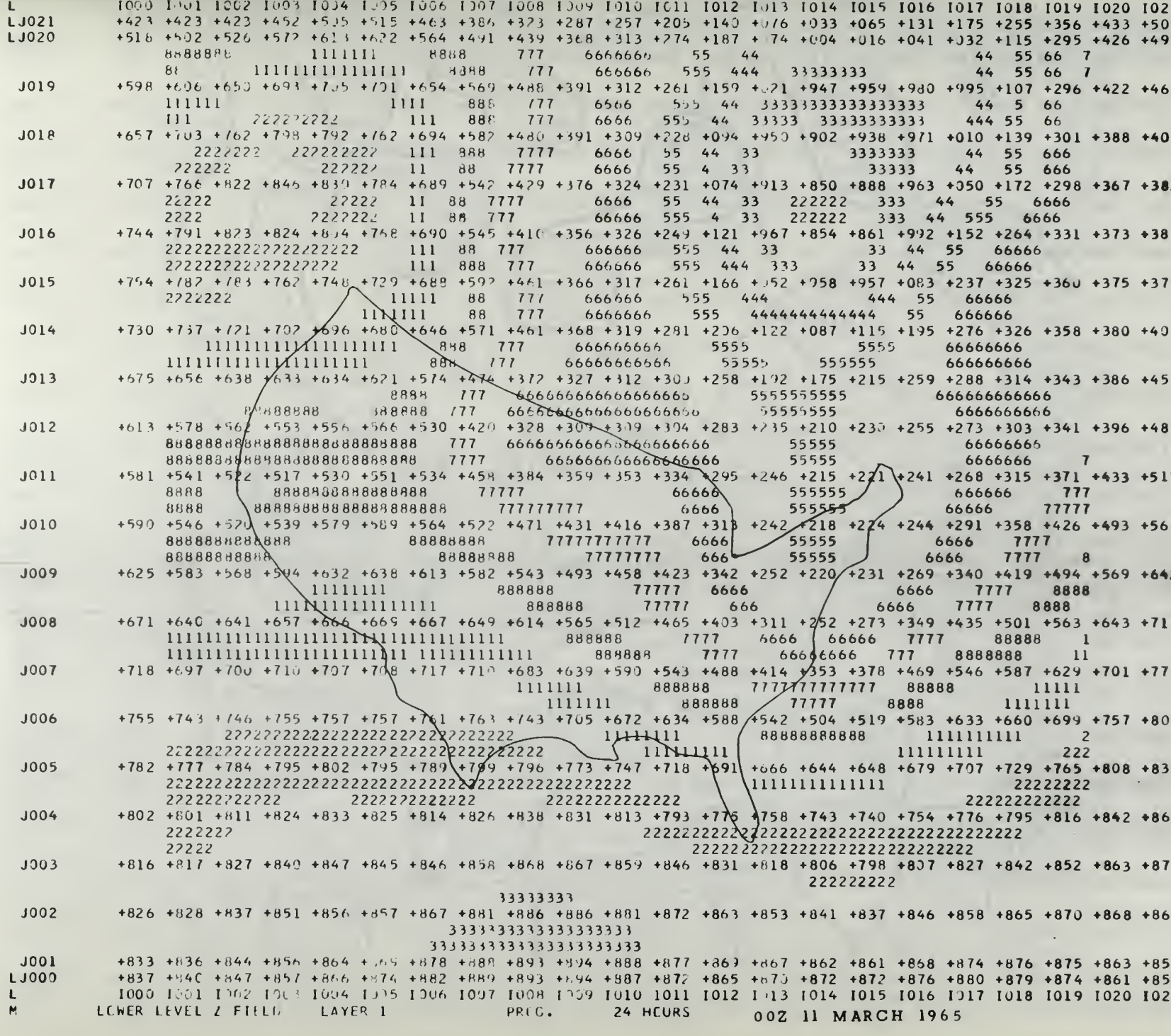
PROG KAI FIELD LAYER 2 PROG. 24 HOURS 12Z 10 MARCH 1965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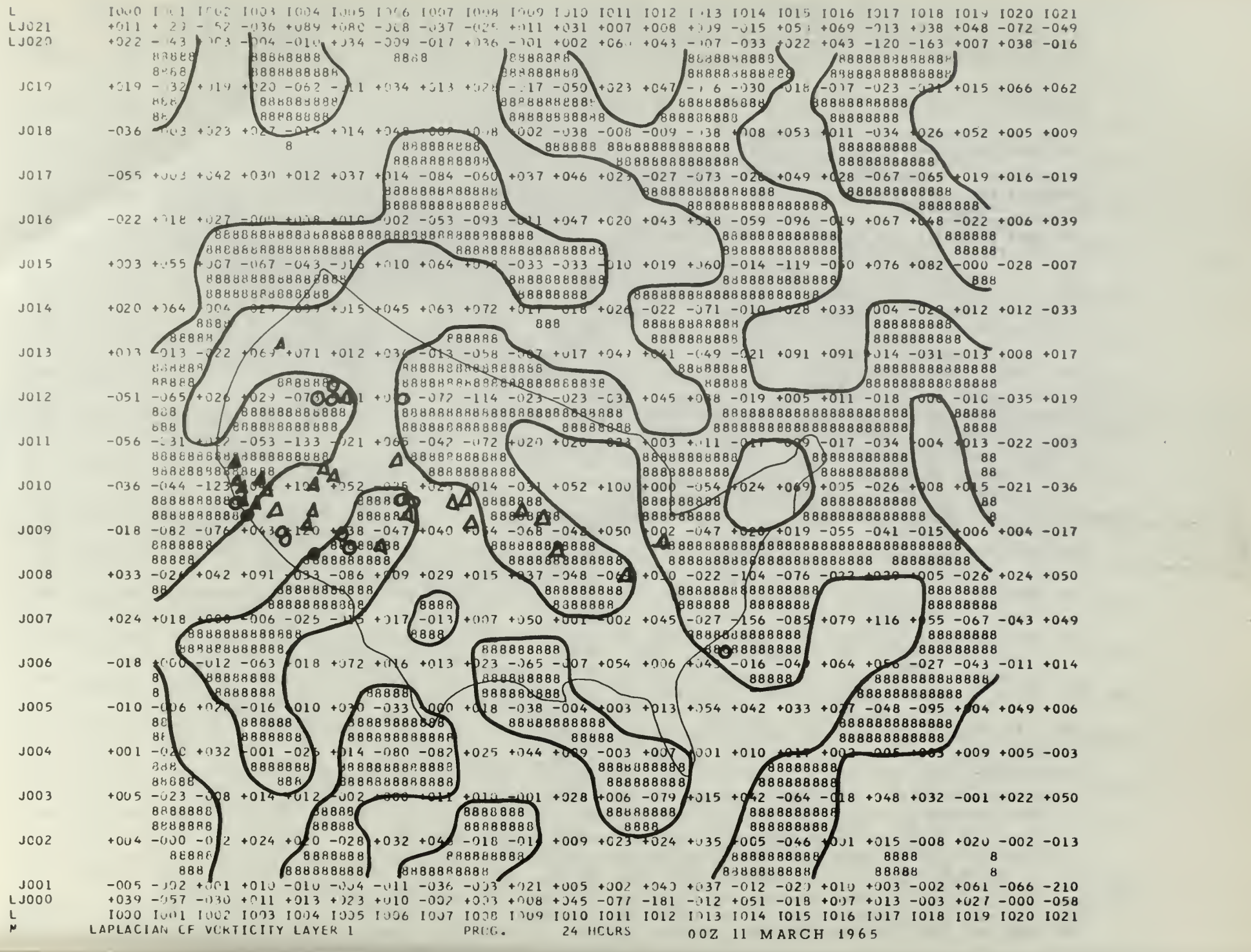
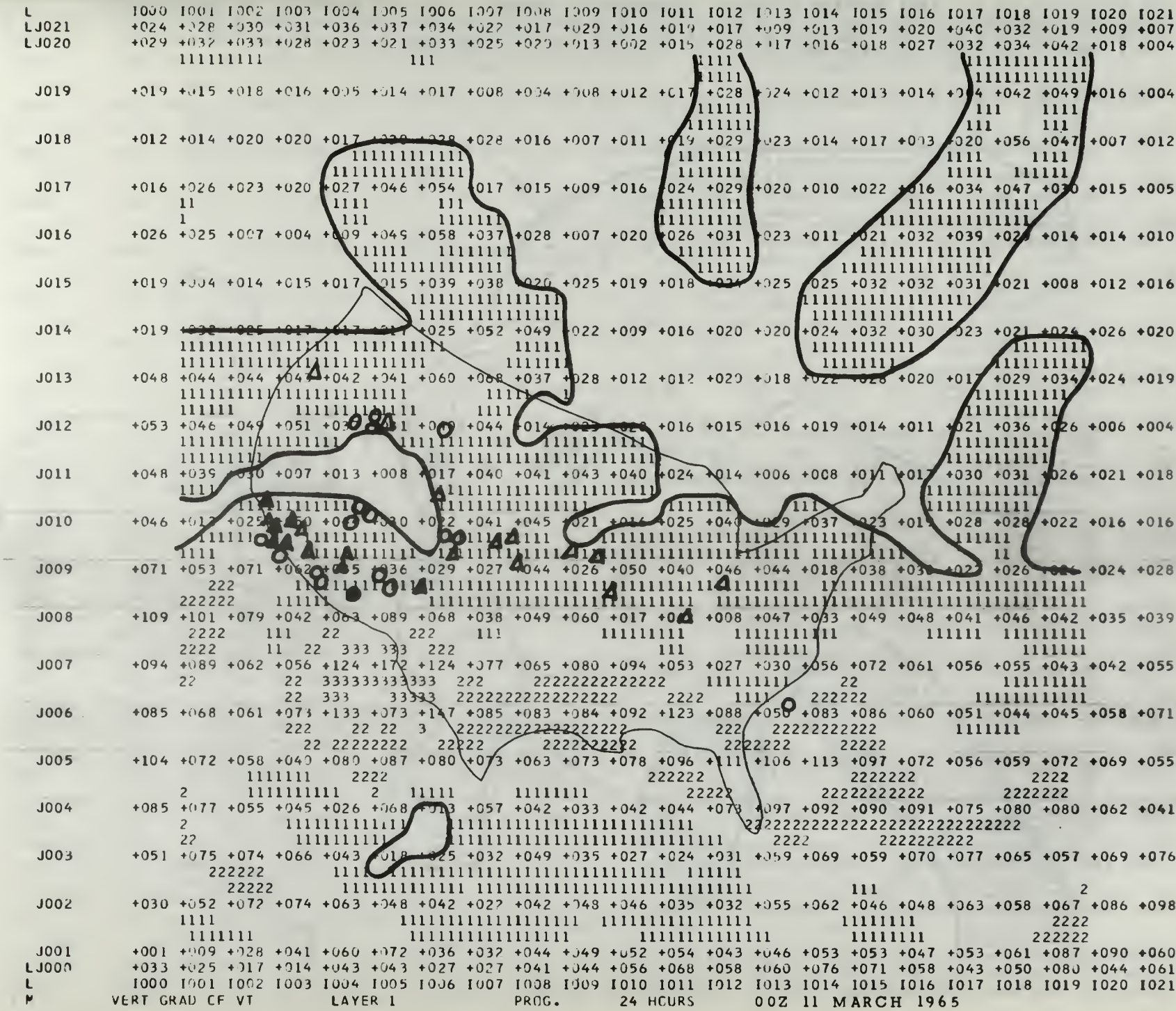
M LOWER LEVEL Z FIELD LAYER 1 PROG. 24 HOURS 00Z 11 MARCH 1965


LAPLACIAN OF VORTICITY LAYER 1
PROG. 24 HOURS
00Z 11 MARCH 1965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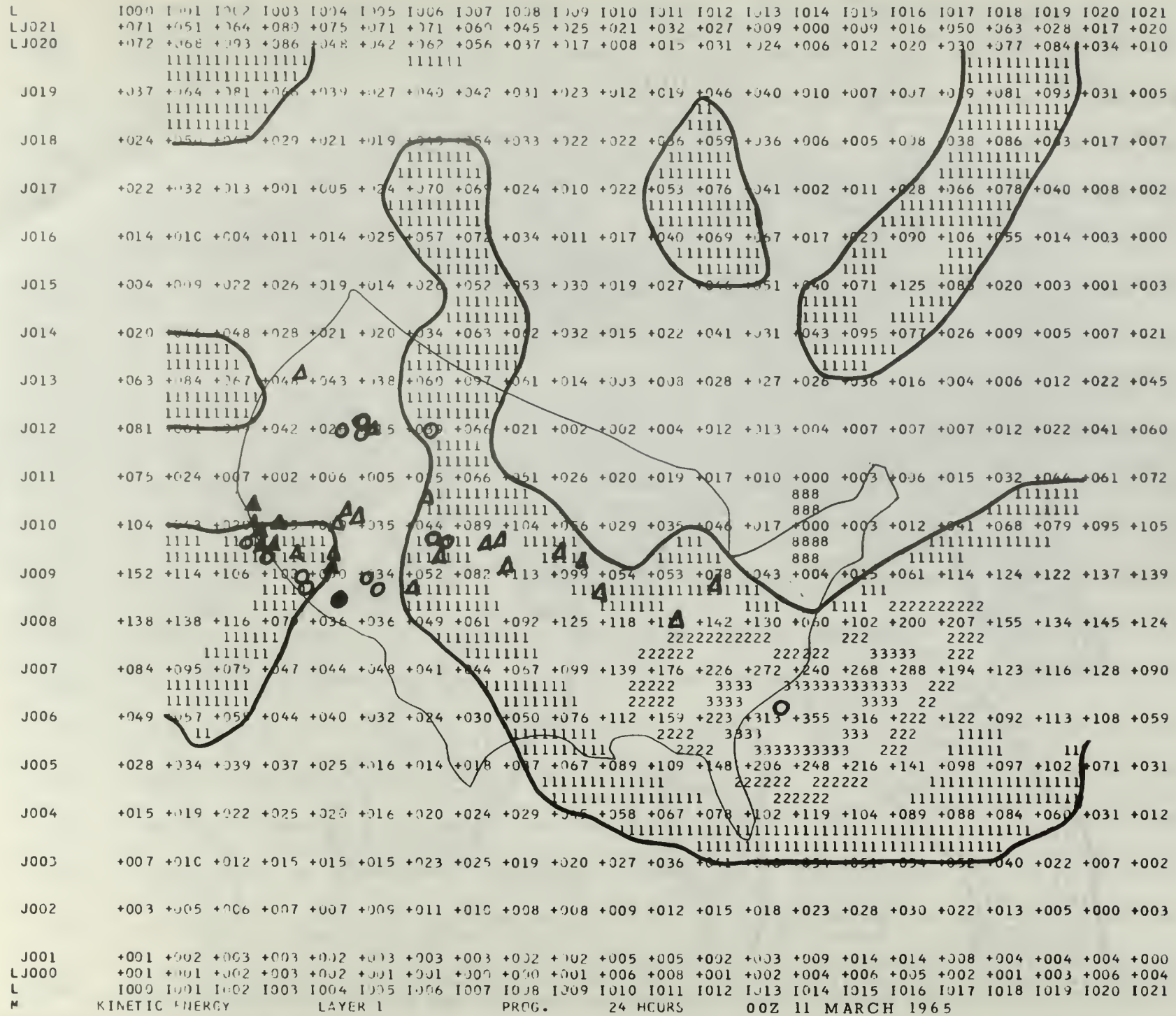
VERT GRAD CF VT
LAYER 1
PROG.
24 HOURS
00Z 11 MARCH 1965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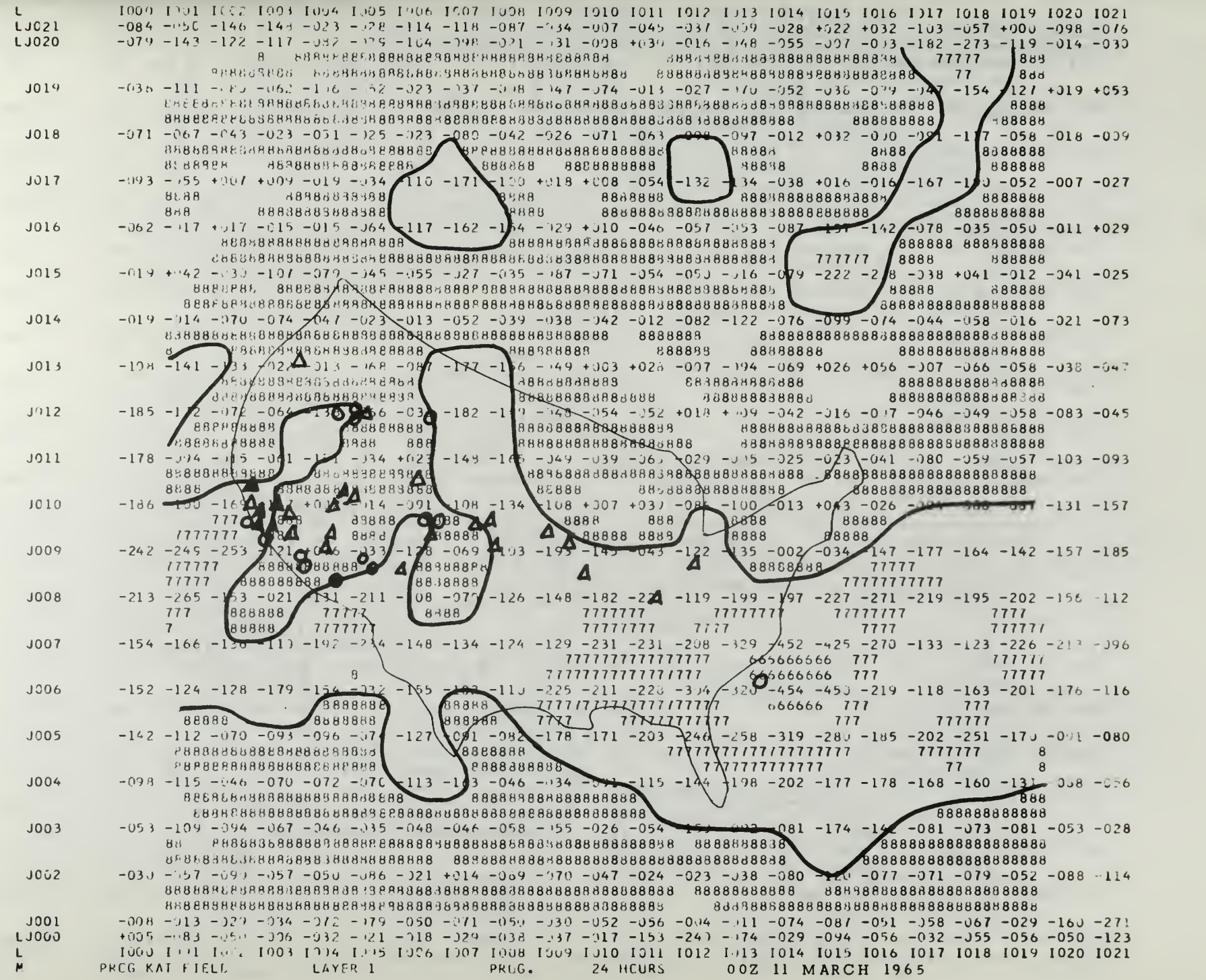
KINETIC ENERGY LAYER 1 PROG. 24 HOURS 00Z 11 MARCH 1965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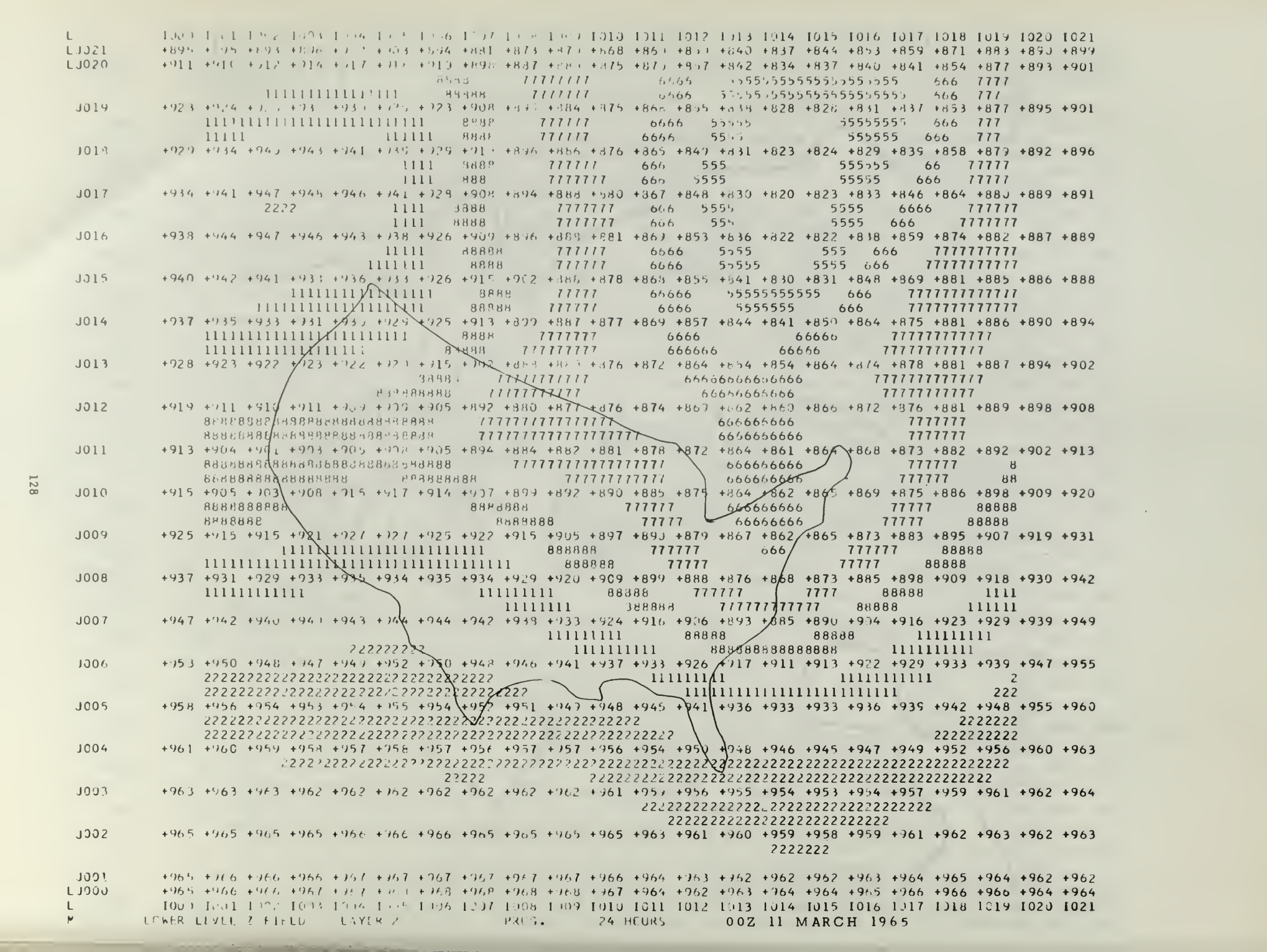
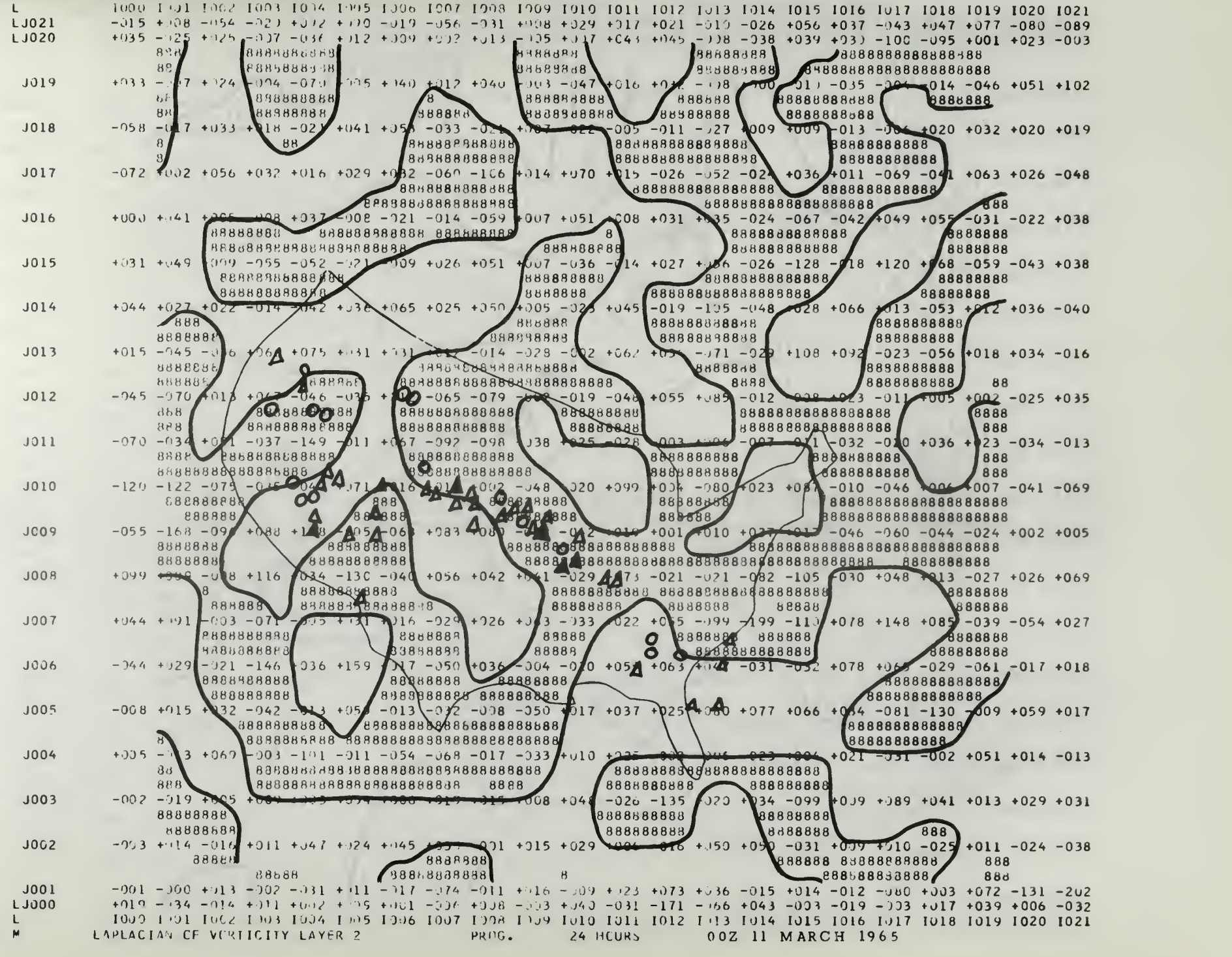
PROG KAT FIELD LAYER 1 PROG. 24 HOURS 00Z 11 MARCH 1965


LOWER LEVEL Z FIELD LAYER Z PROG. 24 HOURS 00Z 11 MARCH 1965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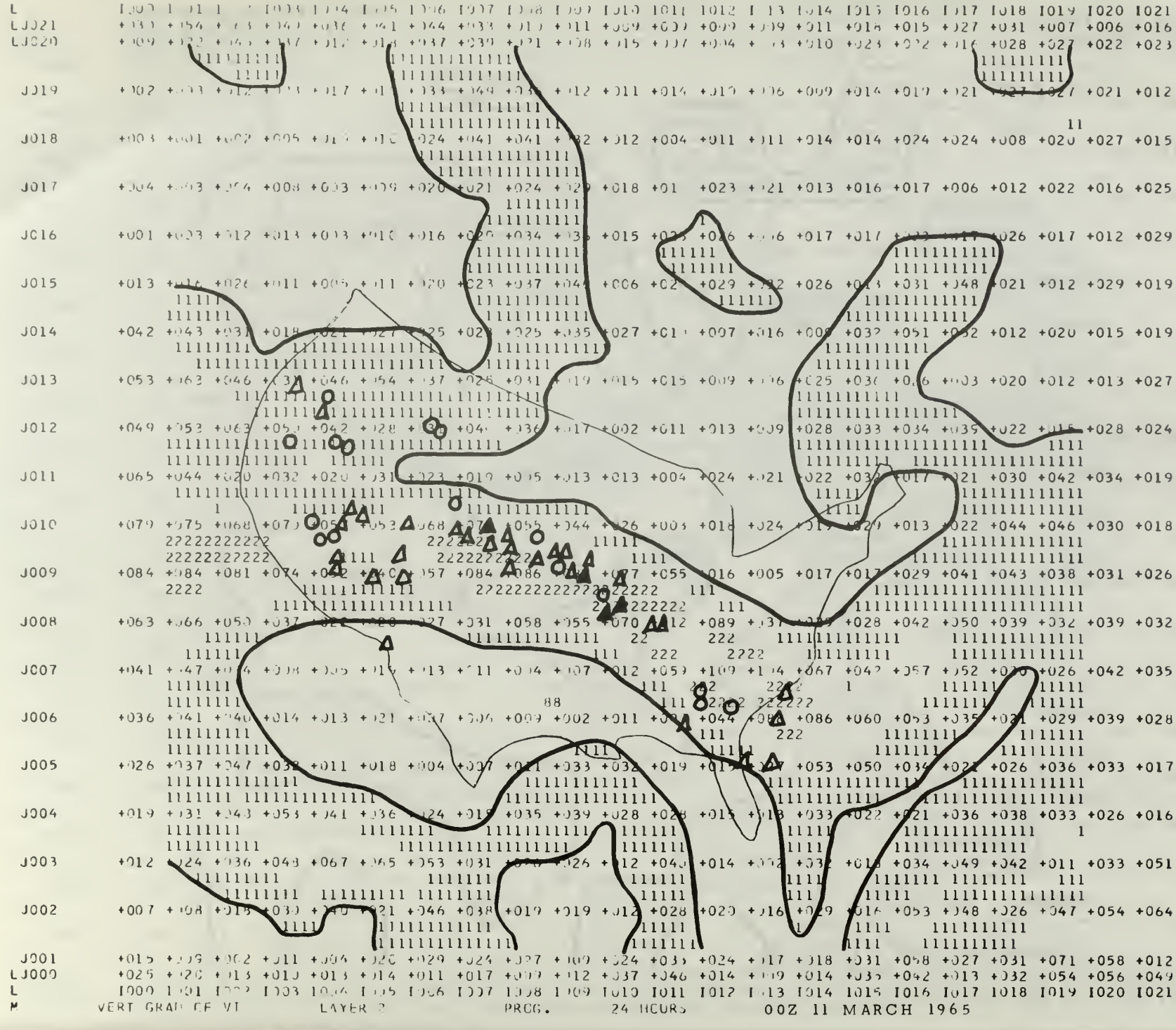
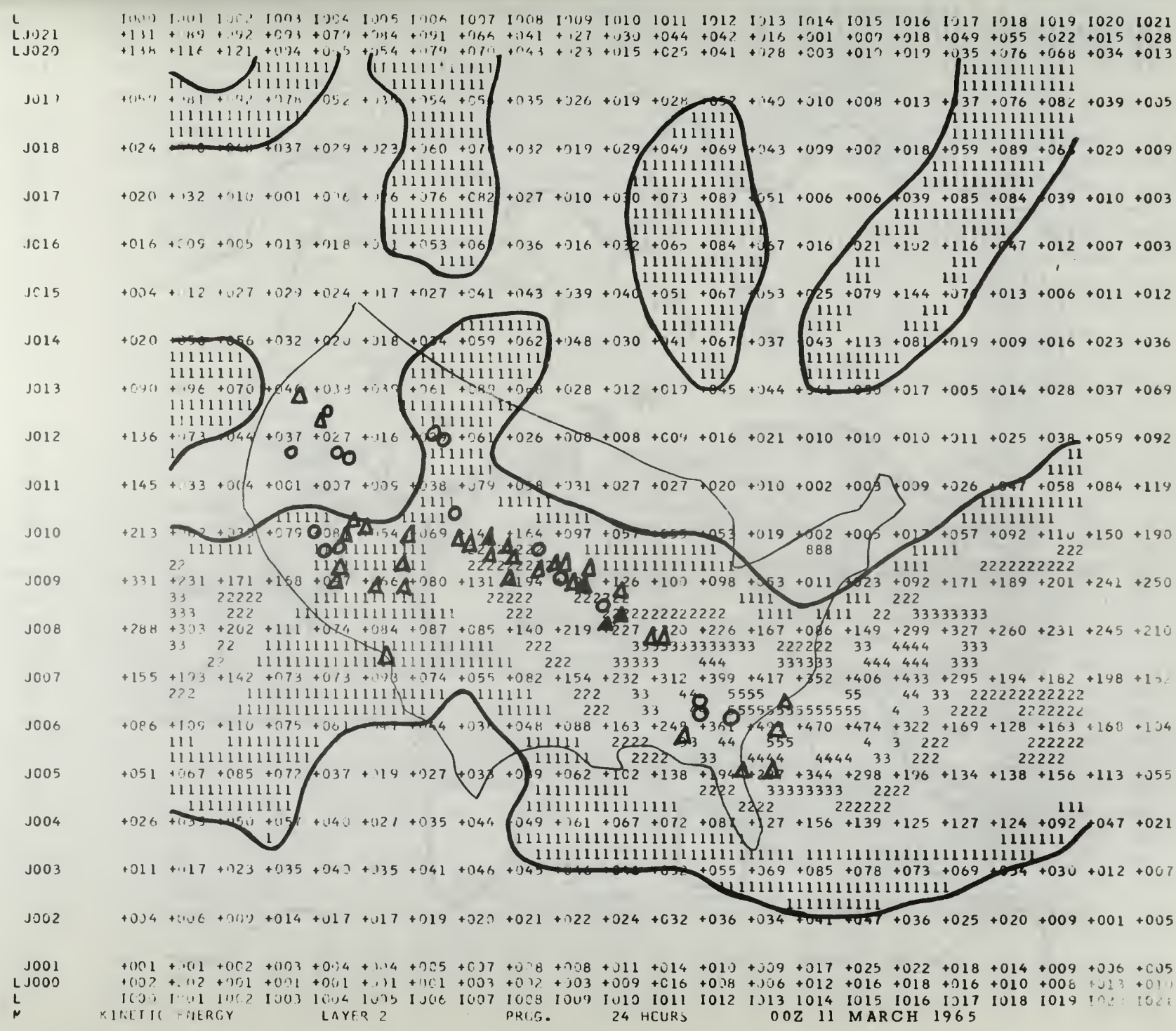
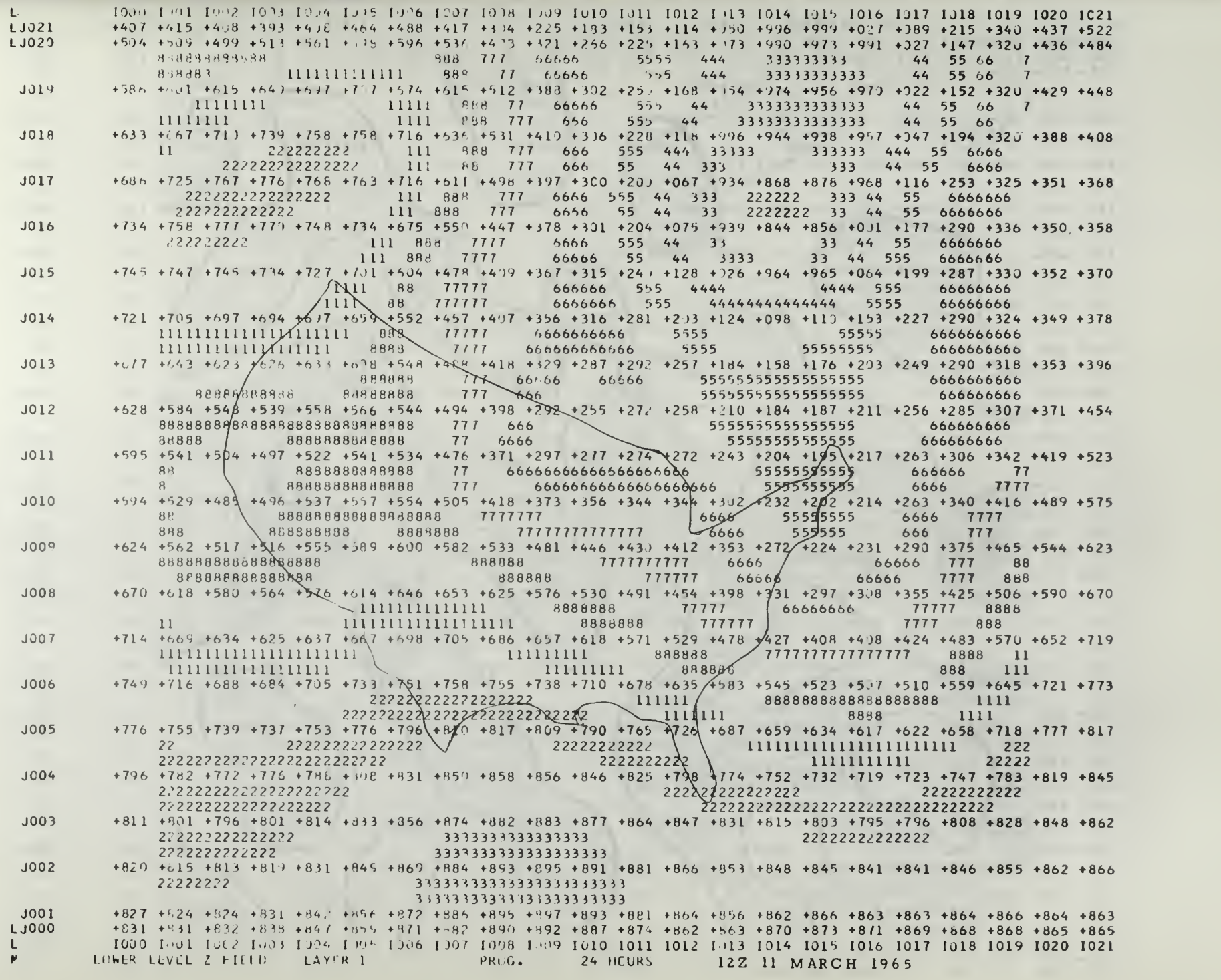
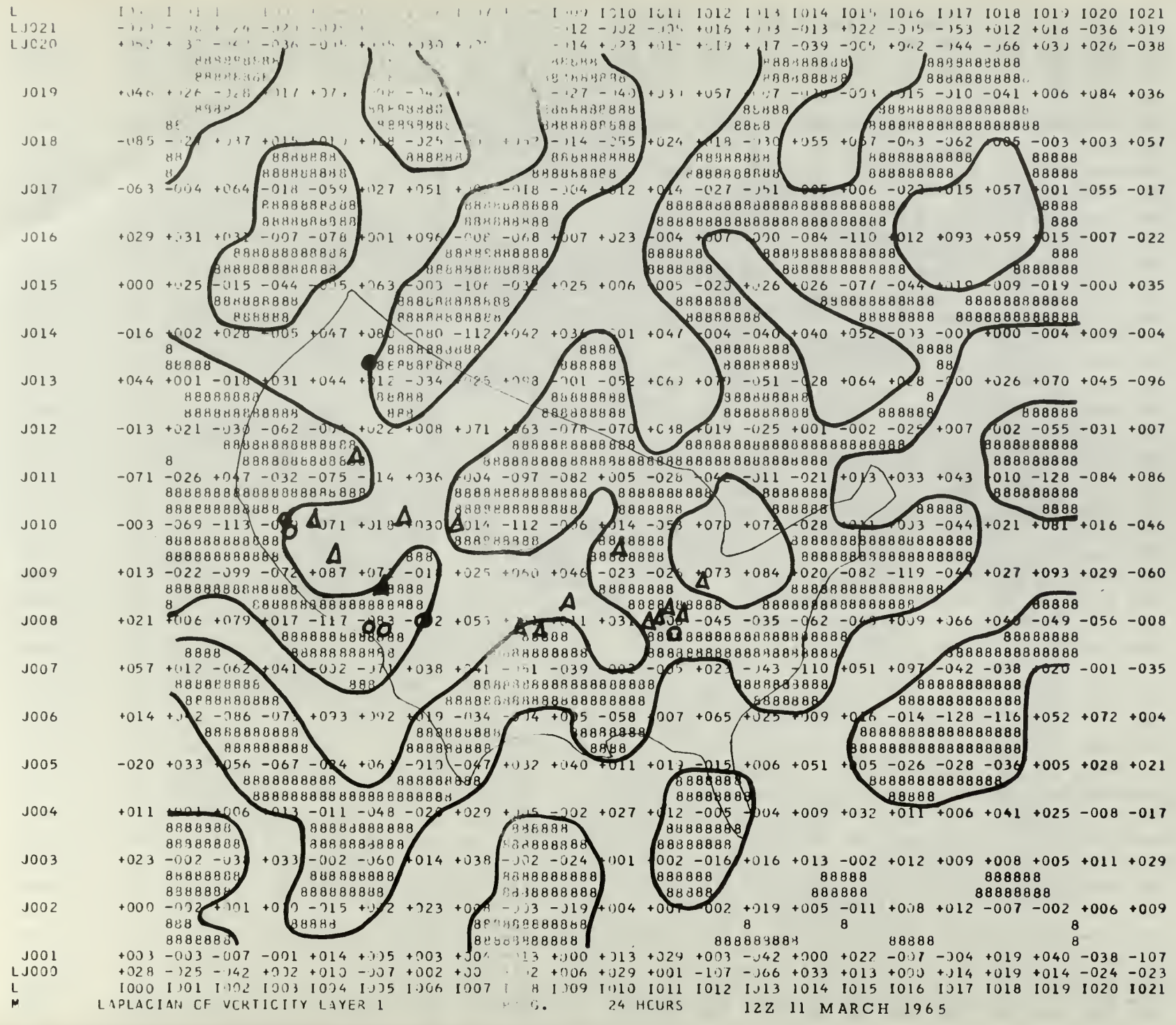
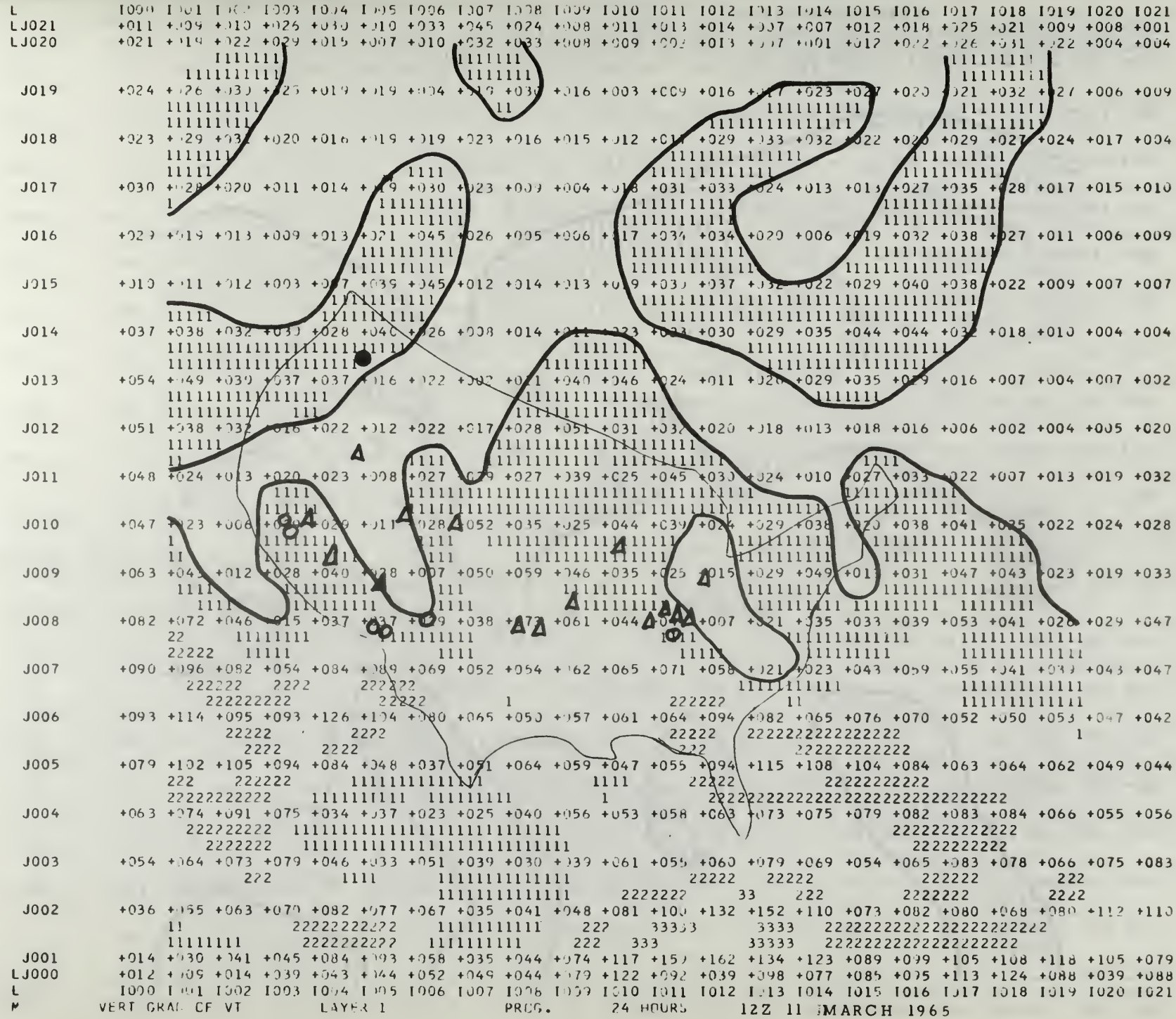

VERT GRAD OF VT
LAYER 2
PROG.
24 HOURS
00Z 11 MARCH 1965


KINETIC ENERGY LAYER 2 PROG. 24 HOURS 00Z 11 MARCH 1965


PROG KAT FIELD
LAYER 2
PROG.
24 HOURS
00Z 11 MARCH 1965


LOWER LEVEL Z FIELD LAYER 1 PROG. 24 HOURS 12Z 11 MARCH 1965


LAPLACIAN OF VORTICITY LAYER 1
24 HOURS
12Z 11 MARCH 1965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J006 +093 +114 +095 +093 +126 +104 +080 +065 +050 +057 +061 +064 +094 +082 +065 +076 +070 +052 +050 +053 +047 +042
J005 +079 +102 +105 +094 +084 +048 +037 +051 +064 +059 +047 +055 +094 +115 +108 +104 +084 +063 +064 +062 +049 +044
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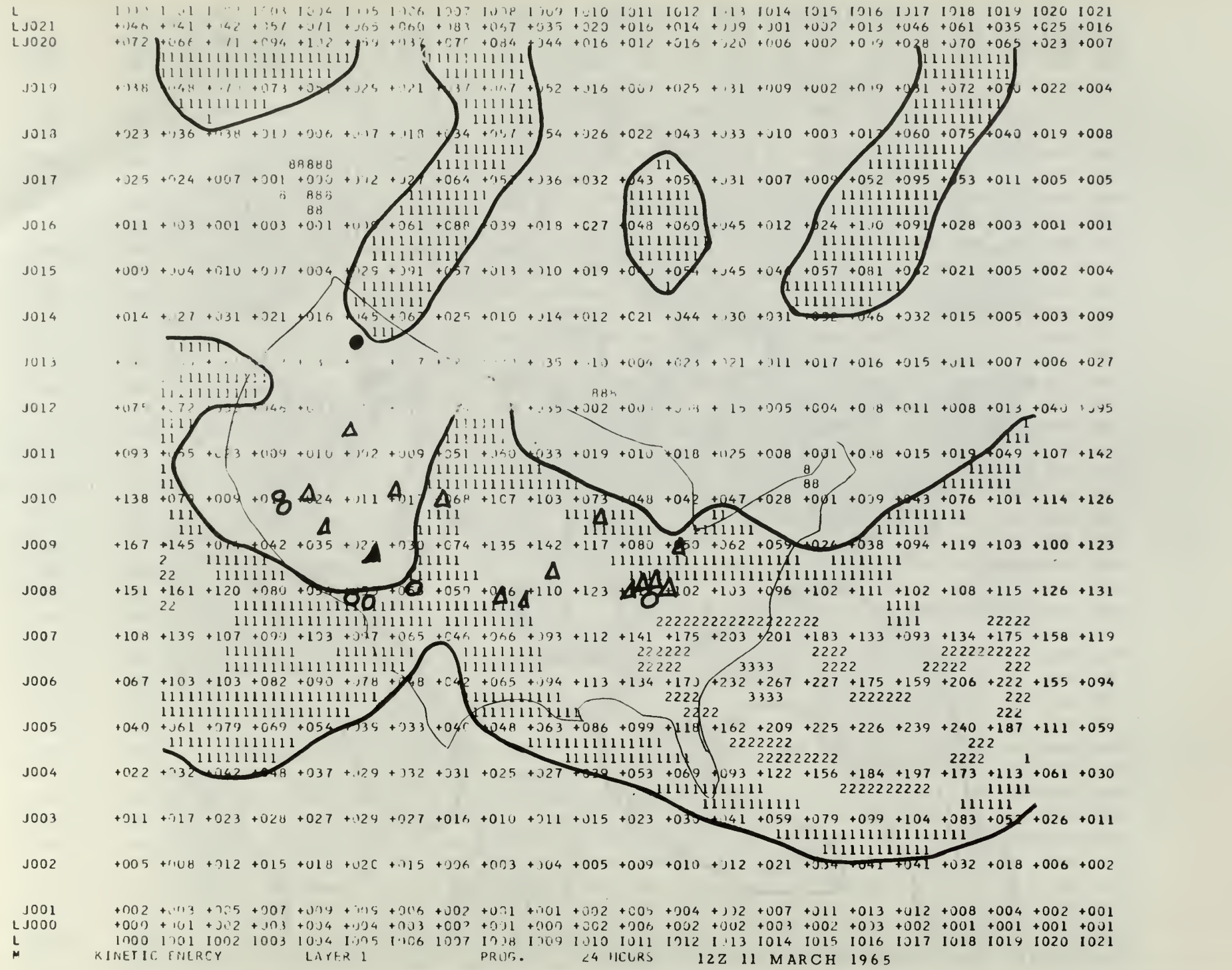
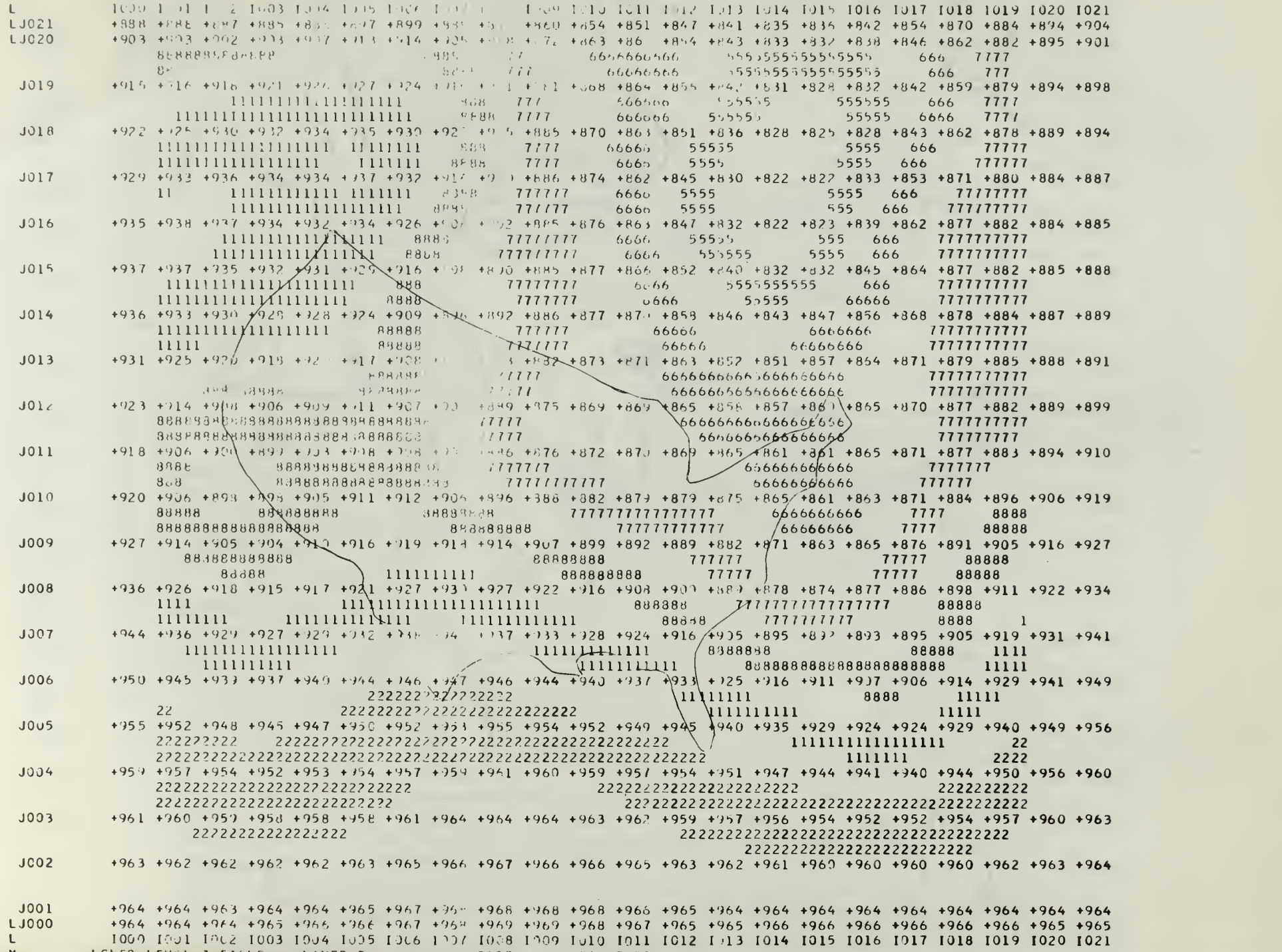
M VERT GRAD OF VT LAYER 1 PROG. 24 HOURS 12Z 11 MARCH 1965


KINETIC ENERGY LAYER 1 PROG. 24 HOURS 12Z 11 MARCH 1965


PROG KAT FIELD LAYER 1 PROG. 24 HOURS 12Z 11 MARCH 1965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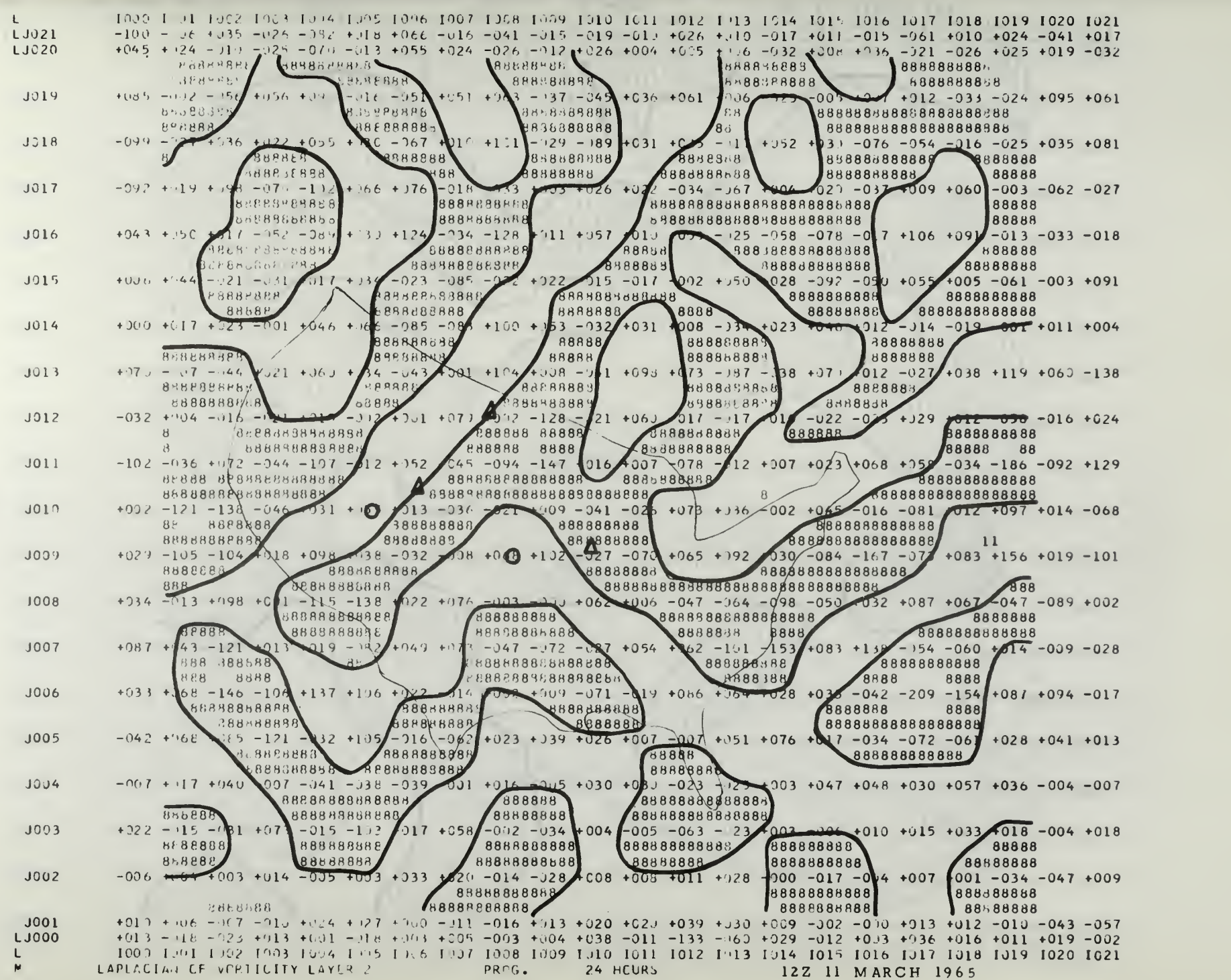
M
LOWER LEVEL 2 FIELD
LAYER 2
PROG.
24 HOURS
12Z 11 MARCH 1965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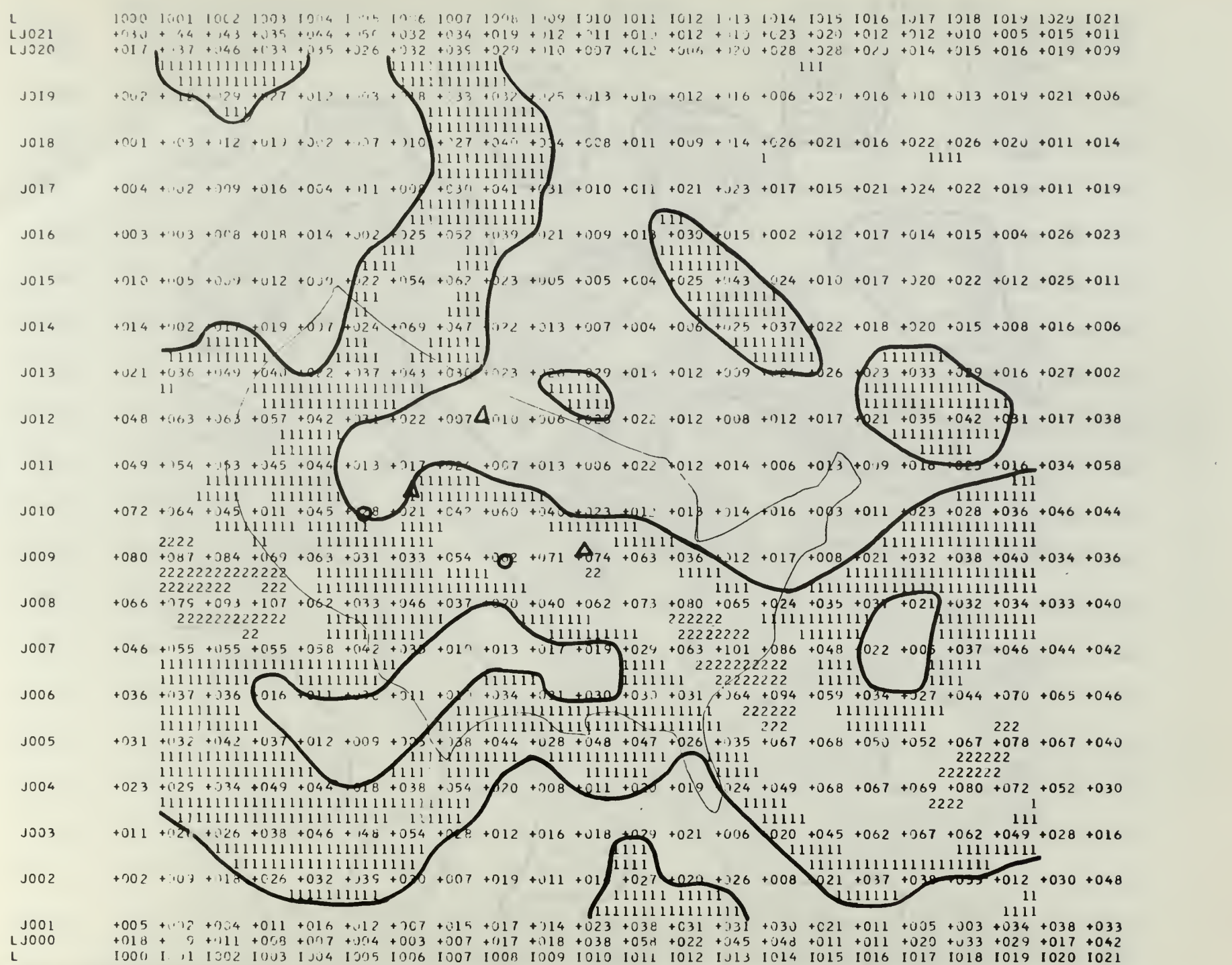
PROG. 24 HOURS
12Z 11 MARCH 1965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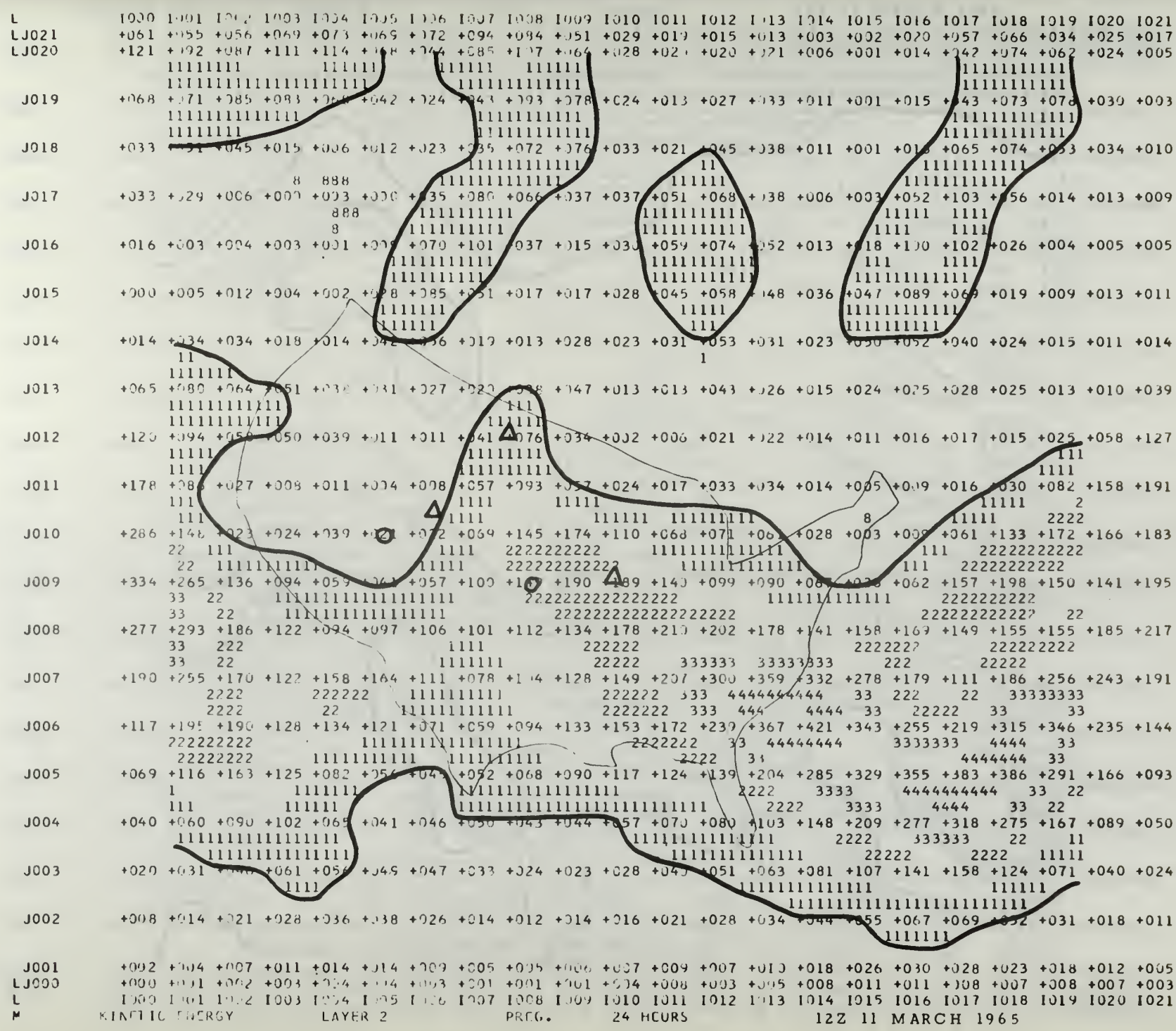
LAYER 2
PROG.
24 HOURS
12Z 11 MARCH 1965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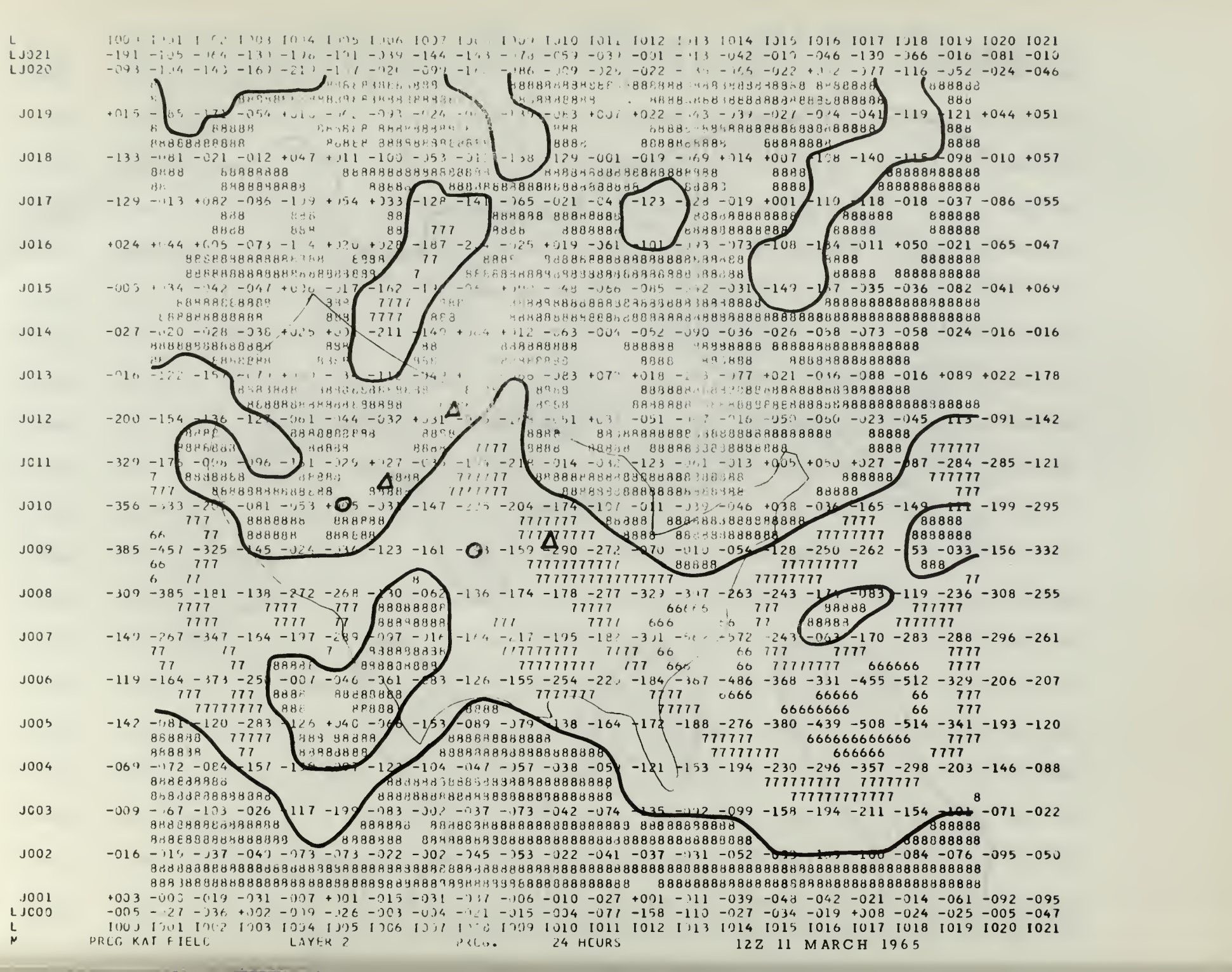
PROG KAT FIELD
LAYER 2
PROG.
24 HOURS
12Z 11 MARCH 1965


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LJ020 +511 +502 +497 +510 +529 +536 +526 +500 +441 +310 +155 +10 +124 +095 +015 +959 +933 +944 +065 +258 +397 +464
J019 +592 +600 +611 +643 +669 +670 +648 +609 +514 +387 +254 +190 +161 +089 +006 +948 +941 +019 +176 +328 +399 +411
J018 +662 +678 +701 +741 +764 +756 +723 +663 +565 +440 +330 +247 +154 +051 +976 +930 +959 +107 +291 +394 +400 +384
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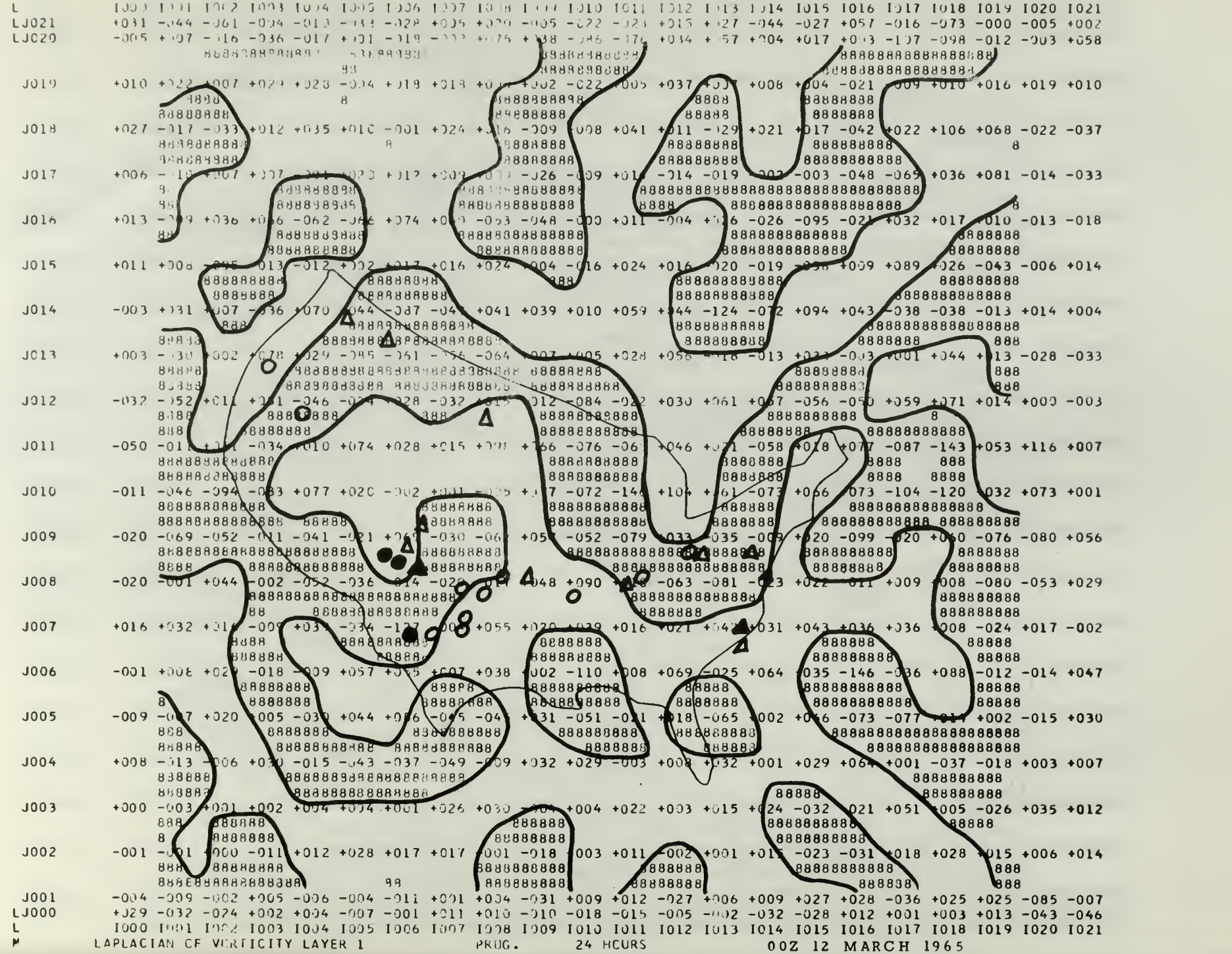
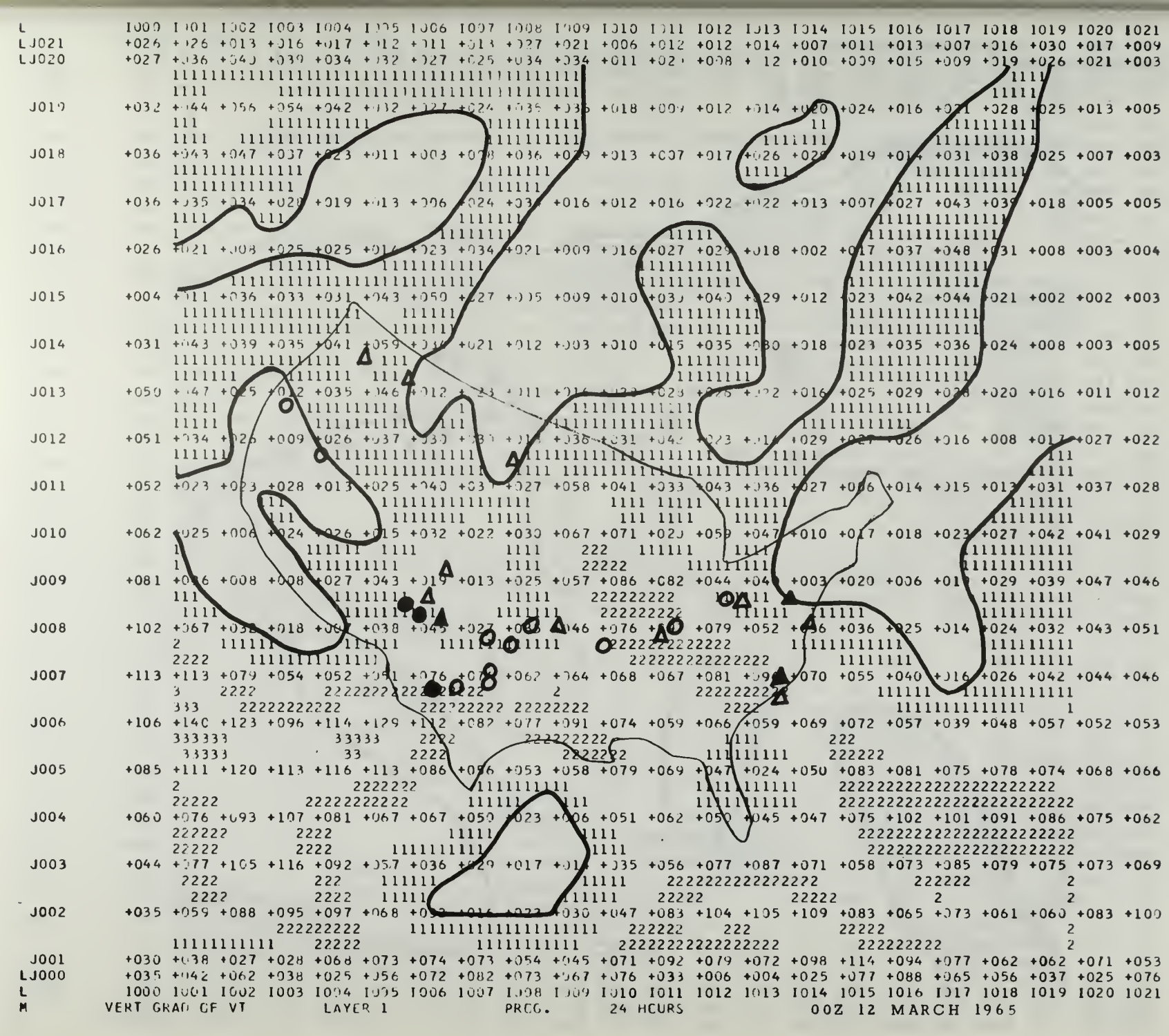
LJ000 +845 +847 +852 +860 +869 +878 +887 +895 +898 +897 +894 +890 +885 +874 +860 +858 +865 +868 +868 +868 +864 +863
L I000 I001 I002 I003 I004 I005 I006 I007 I008 I009 I010 I011 I012 I013 I014 I015 I016 I017 I018 I019 I020 I021
M LOWER LEVEL Z FIELD LAYER 1 PROG. 24 HOURS 00Z 12 MARCH 1965


LAPLACIAN OF VORTICITY LAYER 1
PROG. 24 HOURS
00Z 12 MARCH 1965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LJ020 +027 +036 +040 +039 +034 +032 +027 +025 +034 +034 +011 +021 +008 +012 +010 +009 +015 +009 +019 +026 +021 +003
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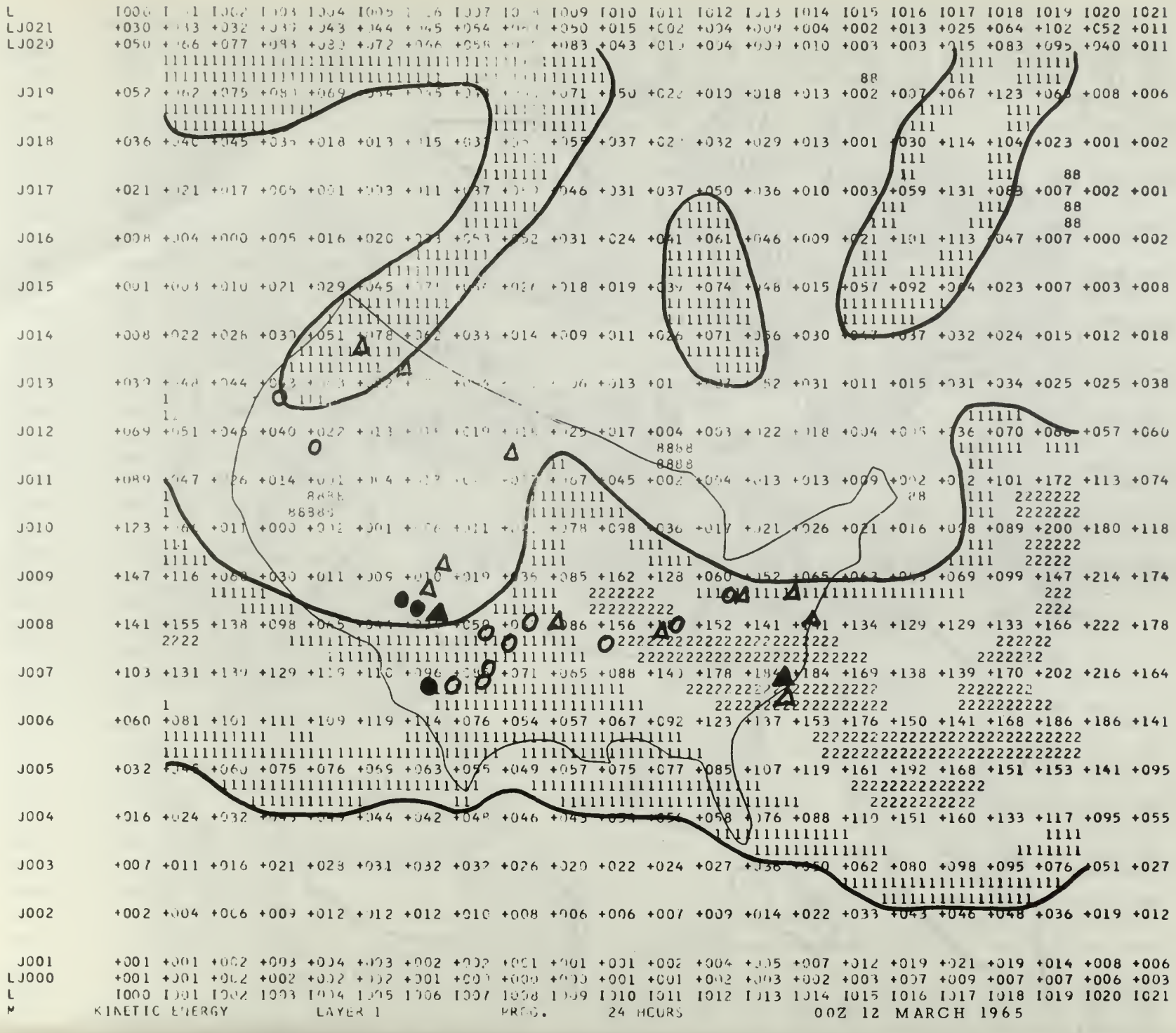
J002 +035 +059 +088 +095 +097 +068 +038 +016 +023 +030 +047 +083 +104 +105 +109 +083 +065 +073 +061 +060 +083 +100
J001 +030 +038 +027 +028 +068 +073 +074 +073 +054 +045 +071 +092 +079 +072 +098 +114 +094 +077 +062 +062 +071 +053
LJ000 +035 +042 +062 +038 +025 +056 +072 +082 +073 +067 +076 +033 +006 +004 +025 +077 +088 +065 +056 +037 +025 +076
L 1000 1001 1002 1003 1004 1005 1006 1007 1008 1009 1010 1011 1012 1013 1014 1015 1016 1017 1018 1019 1020 1021
M VERT GRAD OF VT LAYER 1 PROG. 24 HOURS 00Z 12 MARCH 1965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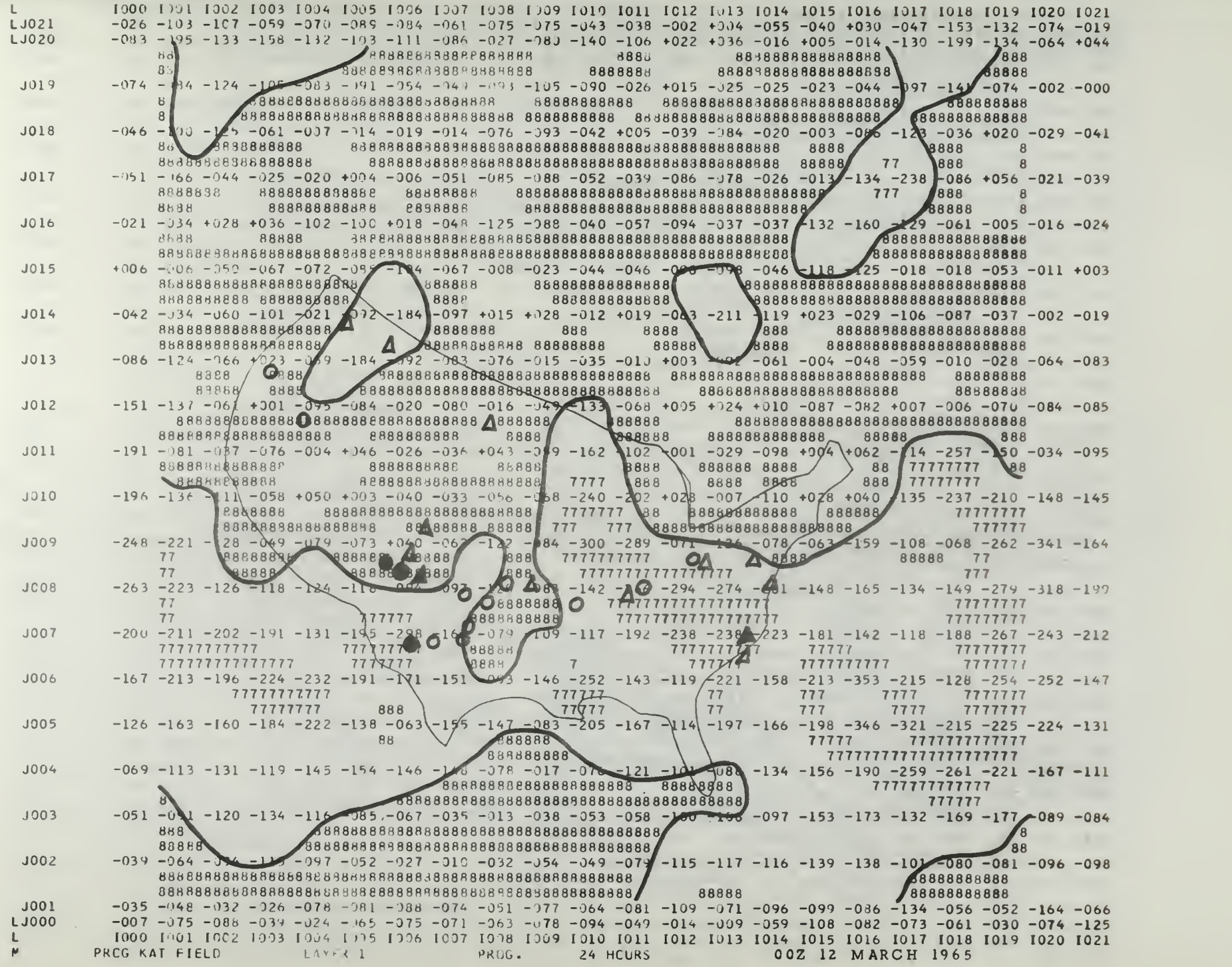
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PRCG KAT FIELD LAYER 1 PROG. 24 HOURS 00Z 12 MARCH 1965


I000 I001 I002 I003 I004 I005 I006 I007 I008 I009 I010 I011 I012 I013 I014 I015 I016 I017 I018 I019 I020 I021
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LJ020 +903 +910 +898 +899 +902 +904 +903 +901 +893 +876 +858 +850 +849 +844 +834 +830 +830 +833 +848 +872 +890 +898
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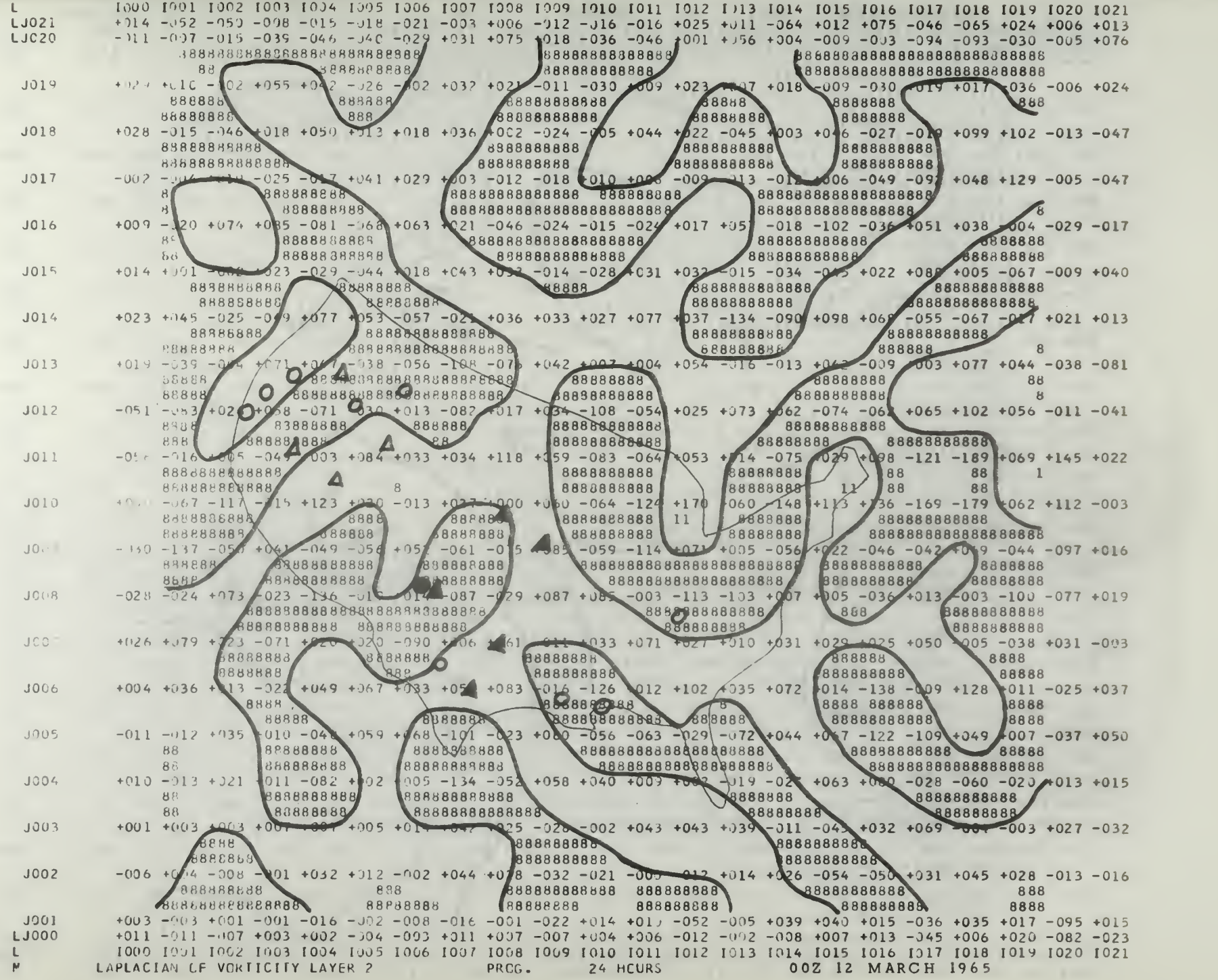
LJ000 +966 +967 +967 +968 +968 +969 +969 +970 +970 +969 +969 +968 +967 +966 +965 +965 +964 +964 +965 +964 +964 +965
L I000 I001 I002 I003 I004 I005 I006 I007 I008 I009 I010 I011 I012 I013 I014 I015 I016 I017 I018 I019 I020 I021
M LOWER LEVEL Z FIELD LAYER 2 PROG. 24 HOURS 00Z 12 MARCH 1965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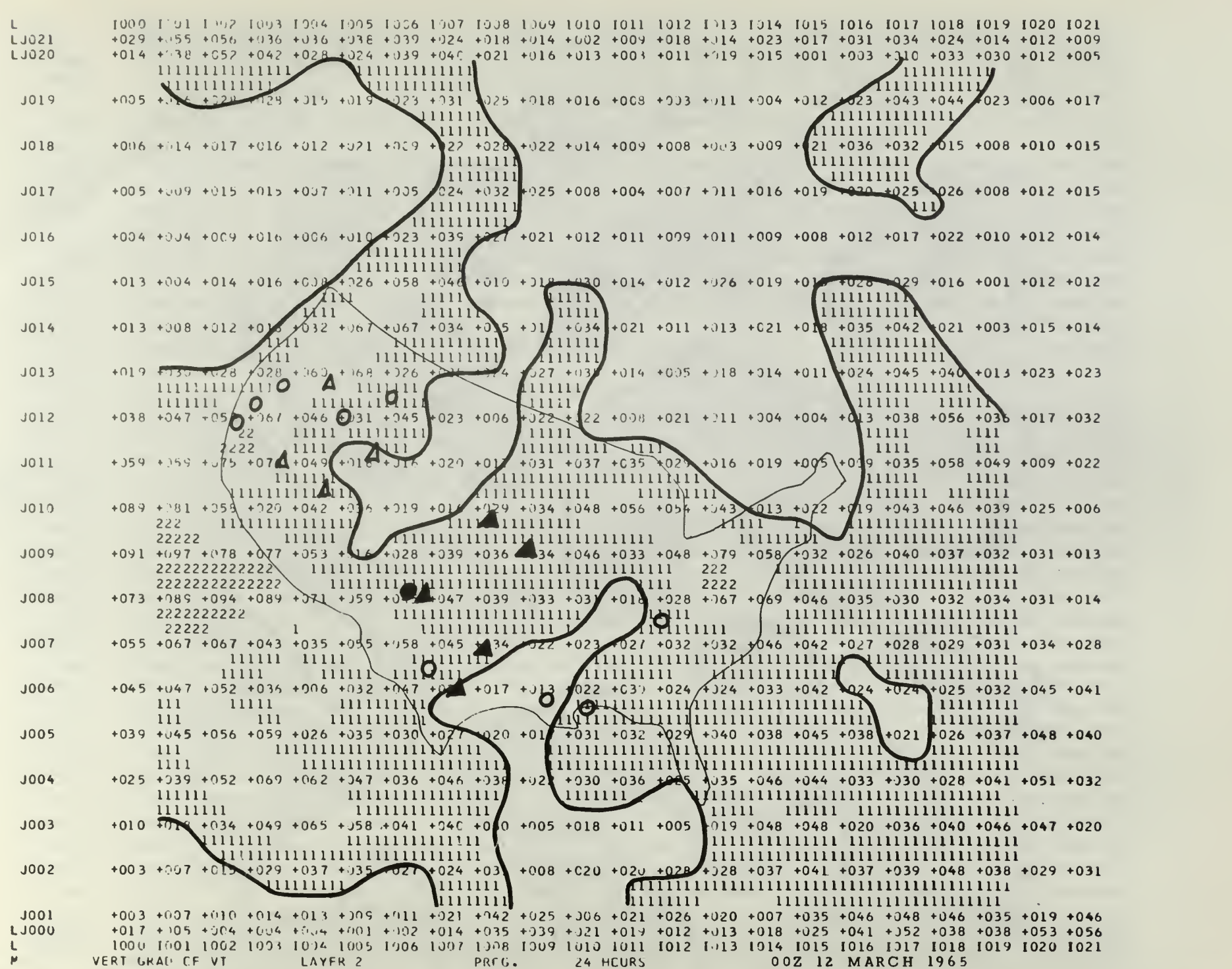
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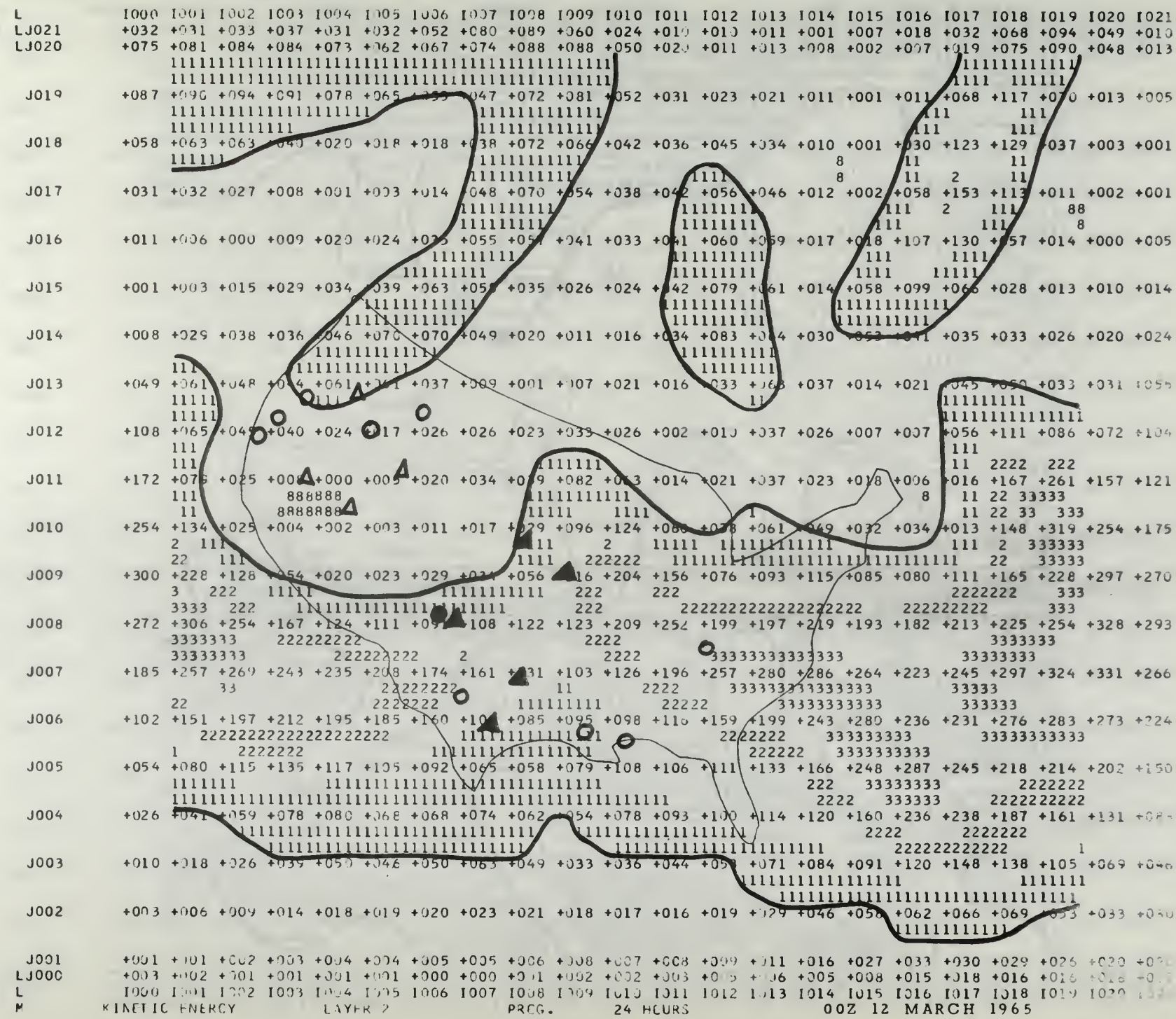
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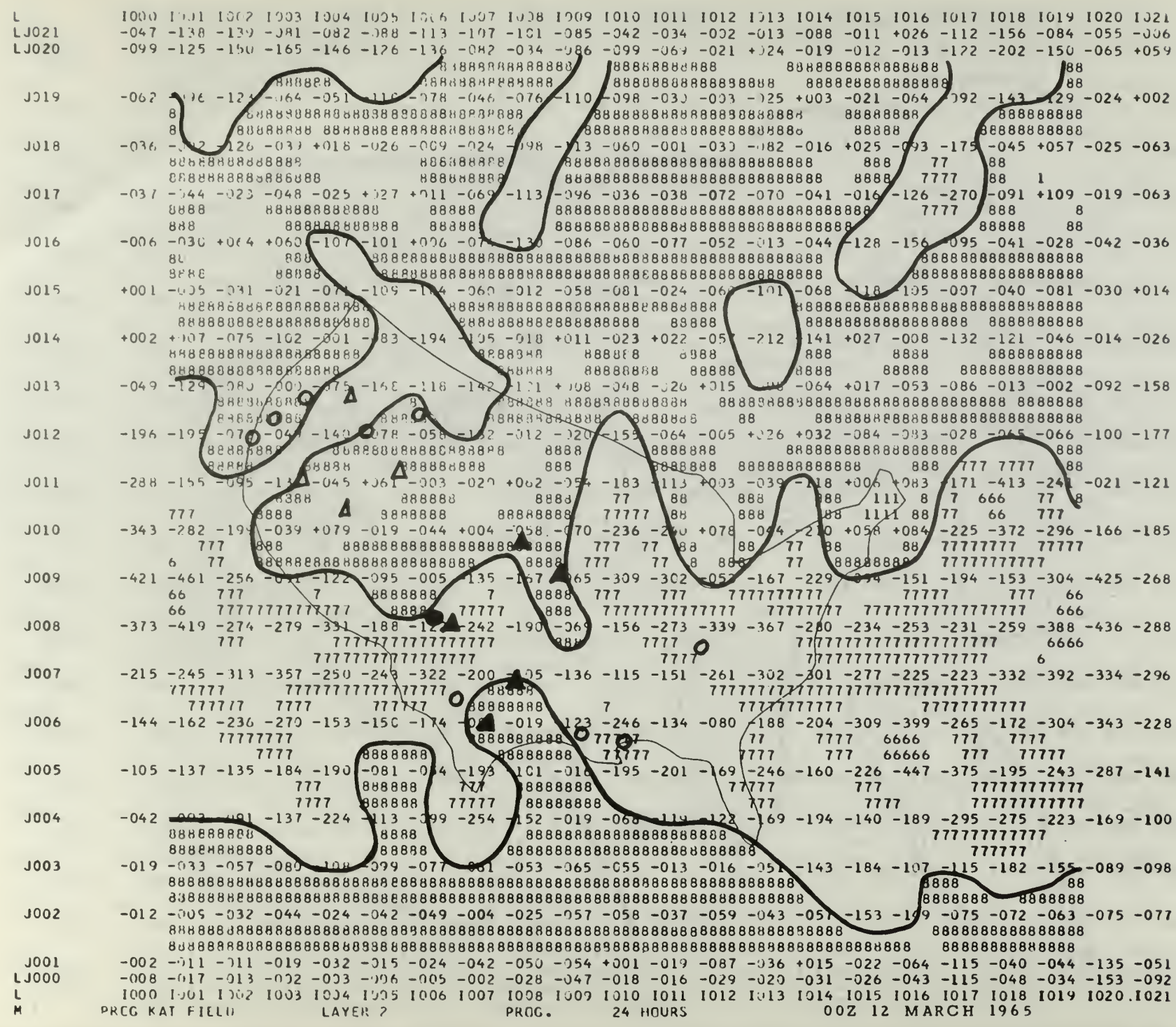
KINETIC ENERGY
LAYER 2
PROG.
24 HOURS
00Z 12 MARCH 1965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M PROG KAT FIELD LAYER 2 PROG. 24 HOURS 00Z 12 MARCH 1965


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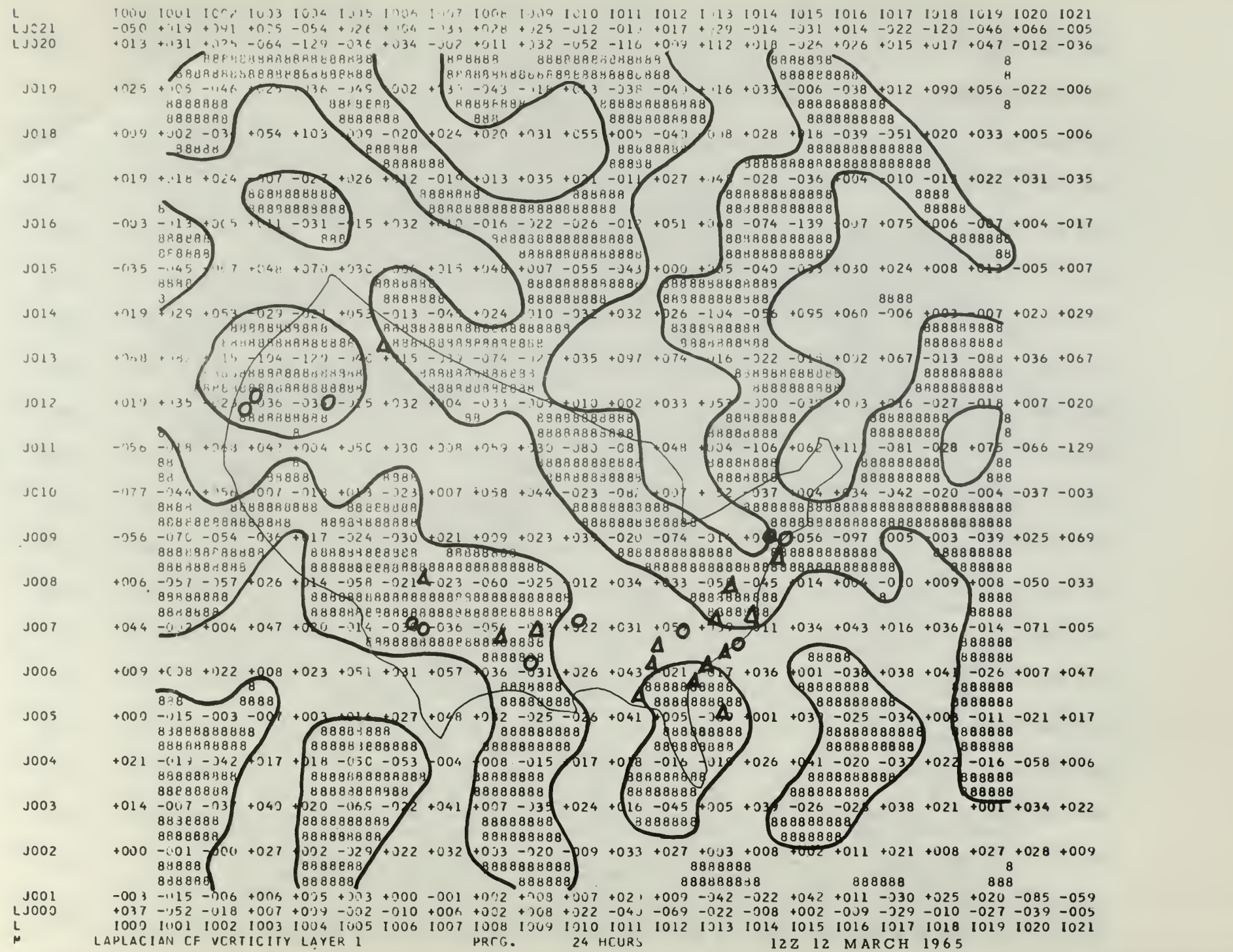
PROG. 24 HOURS
12Z 12 MARCH 1965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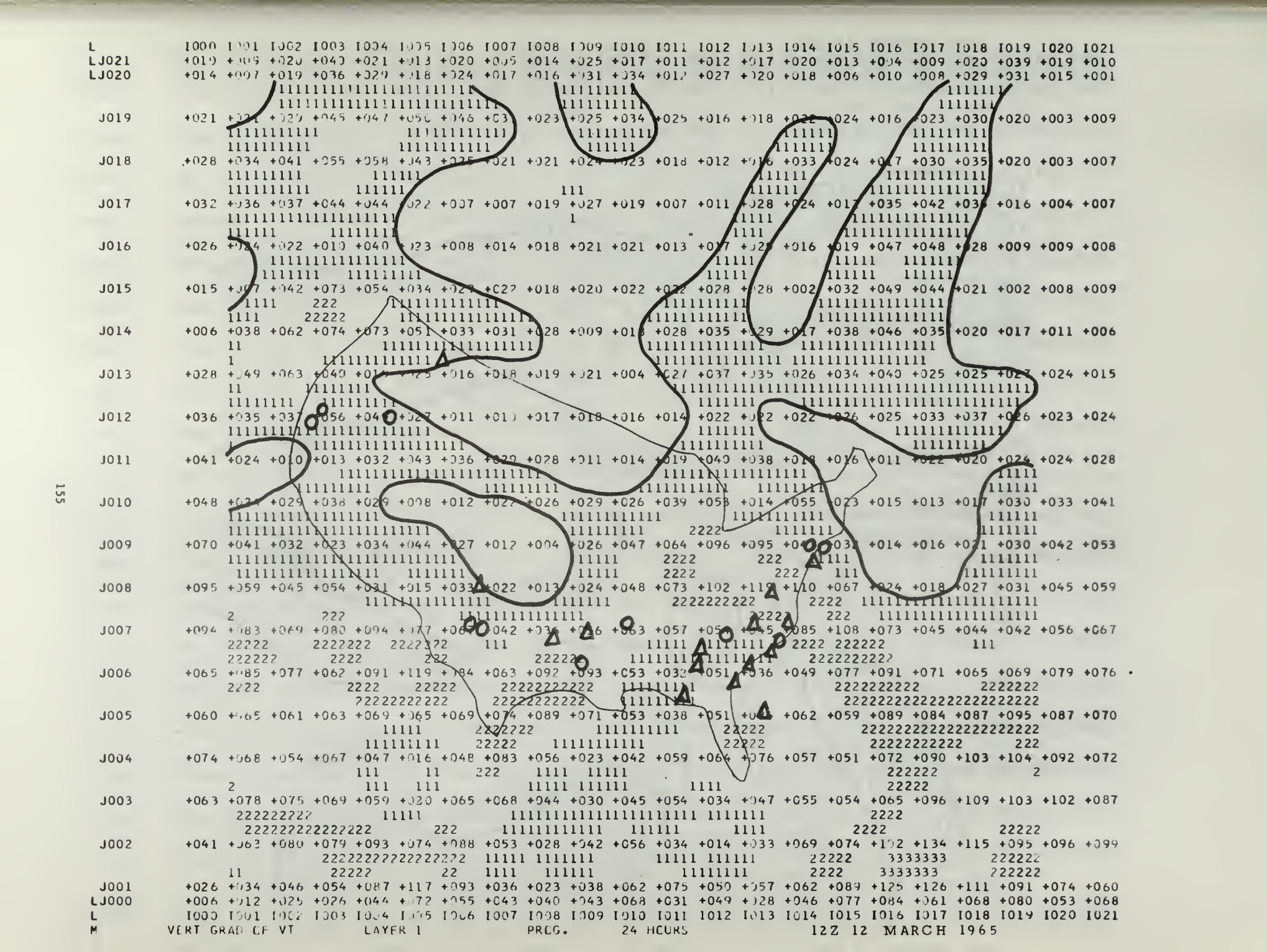
PROG. 24 HOURS
12Z 12 MARCH 1965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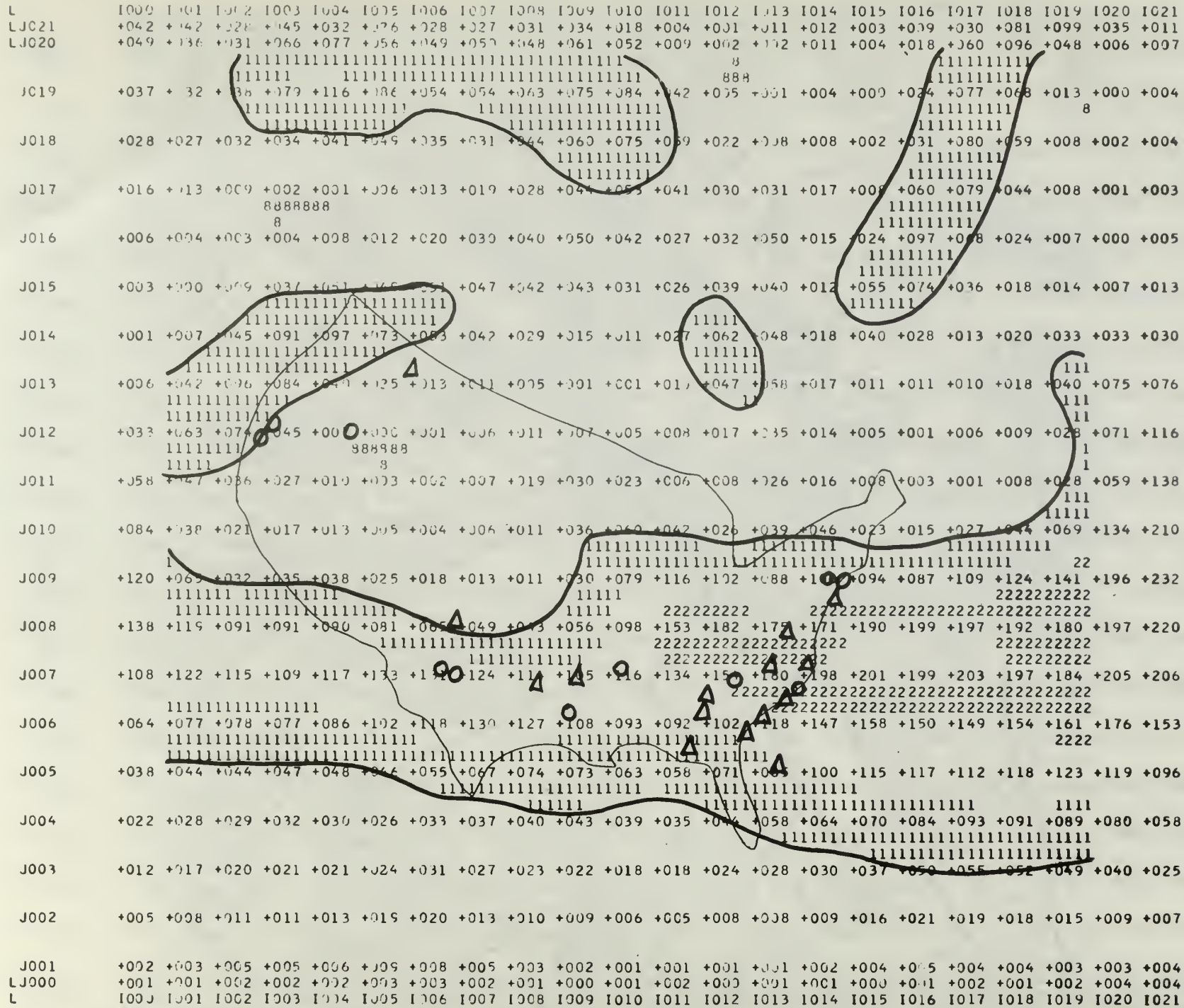
VERT GRAD OF VT
LAYER 1
PROG.
24 HOURS
12Z 12 MARCH 1965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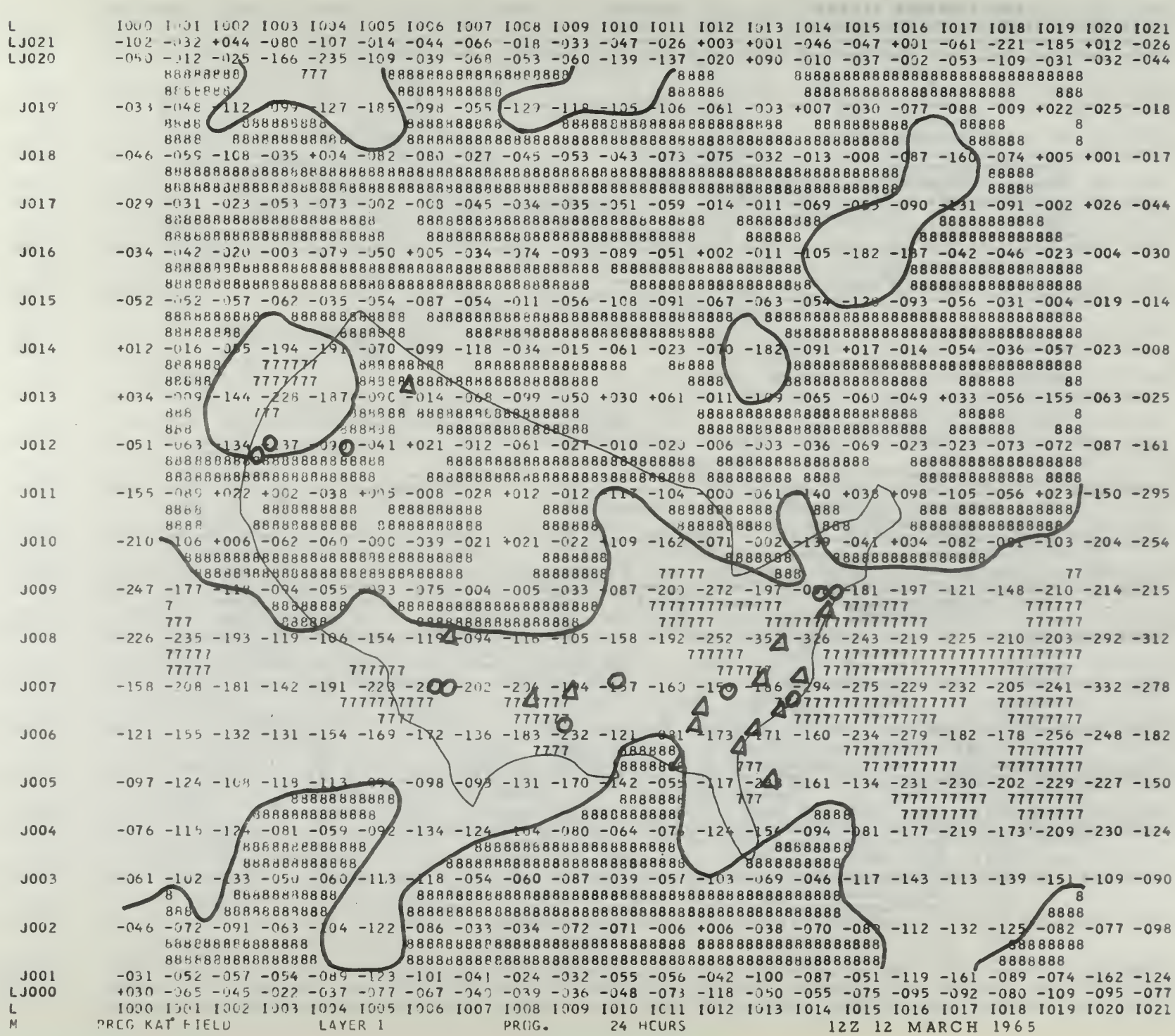
KINETIC ENERGY LAYER 1 PROG. 24 HOURS 12Z 12 MARCH 1965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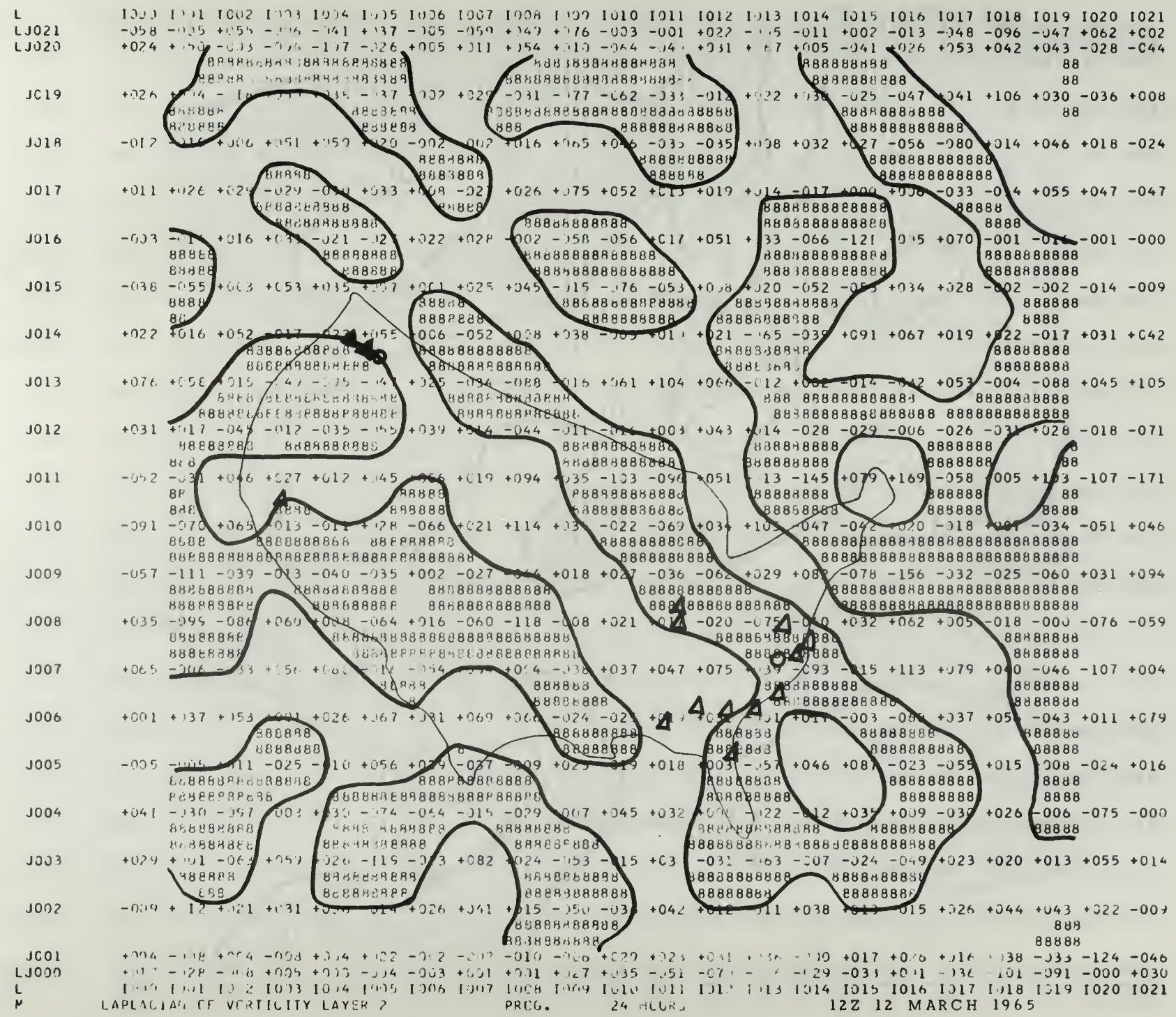
M PROG KAT FIELD LAYER 1 PROG. 24 HOURS 12Z 12 MARCH 1965


LOWER LEVEL Z FIELD LAYER 2
PROG. 24 HOURS
12Z 12 MARCH 1965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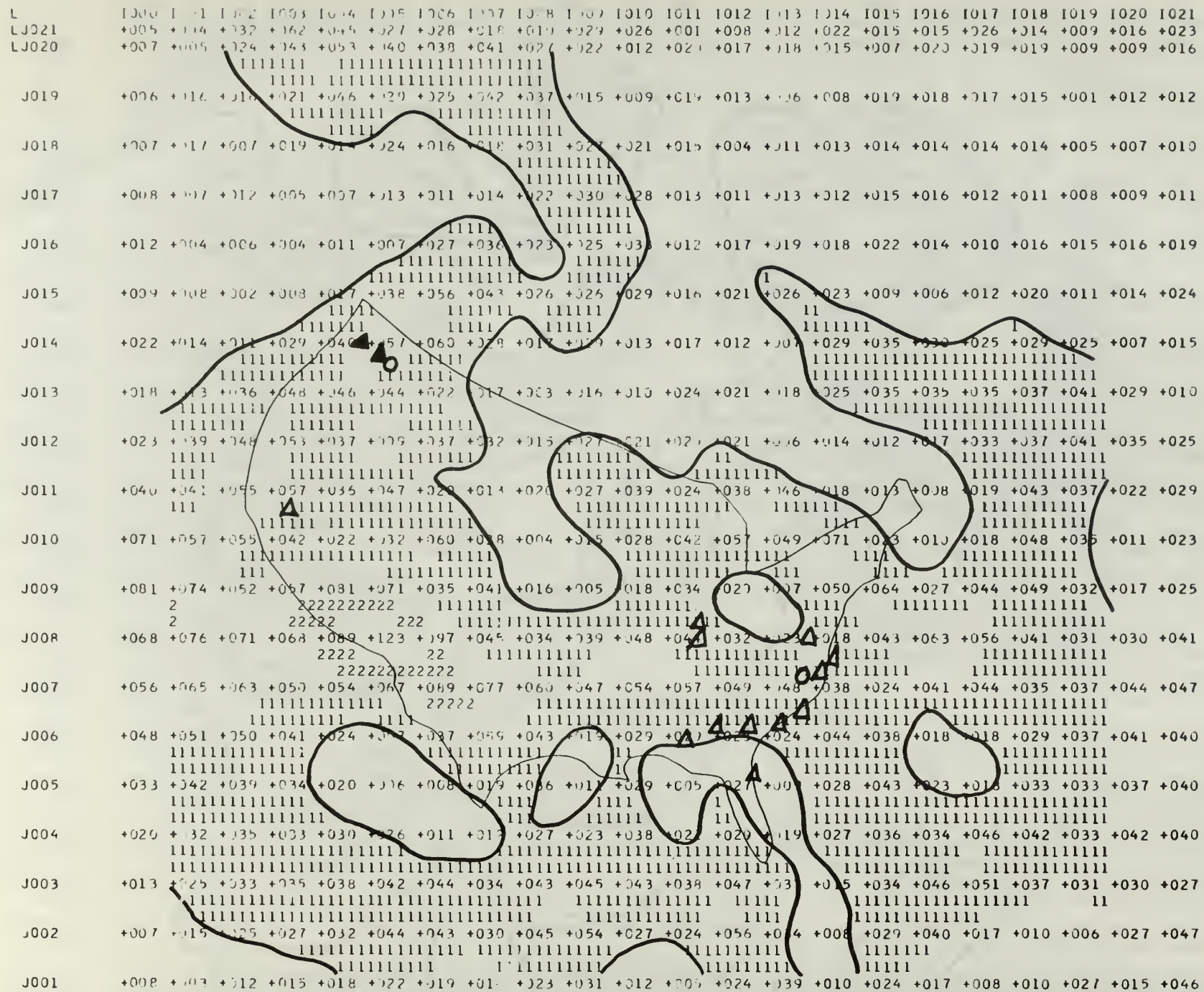
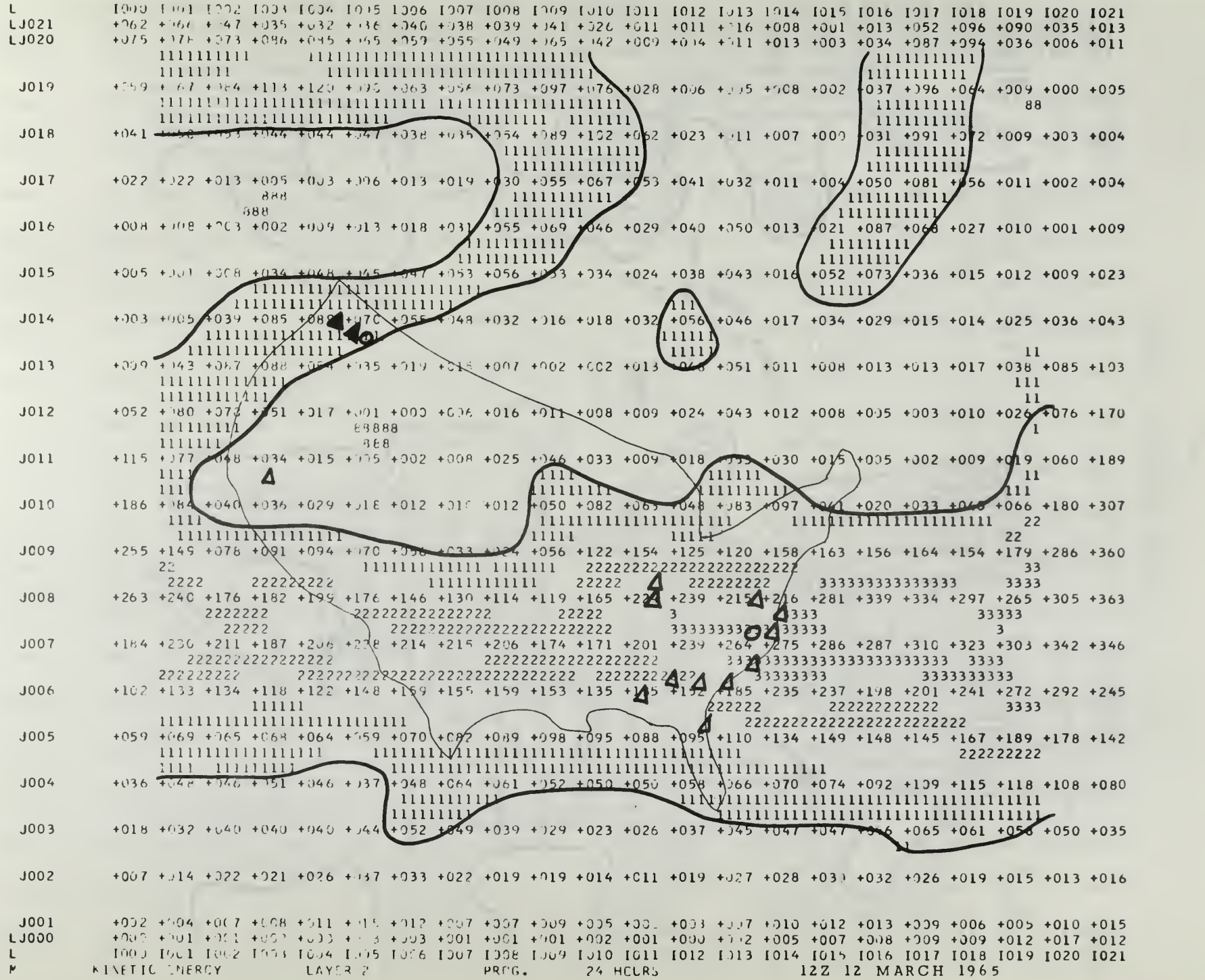

VERT GRAD OF VT
LAYER 2
PROG. 24 HOURS
12Z 12 MARCH 1965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KINETIC ENERGY LAYER 2 PROG. 24 HOURS 12Z 12 MARCH 1965

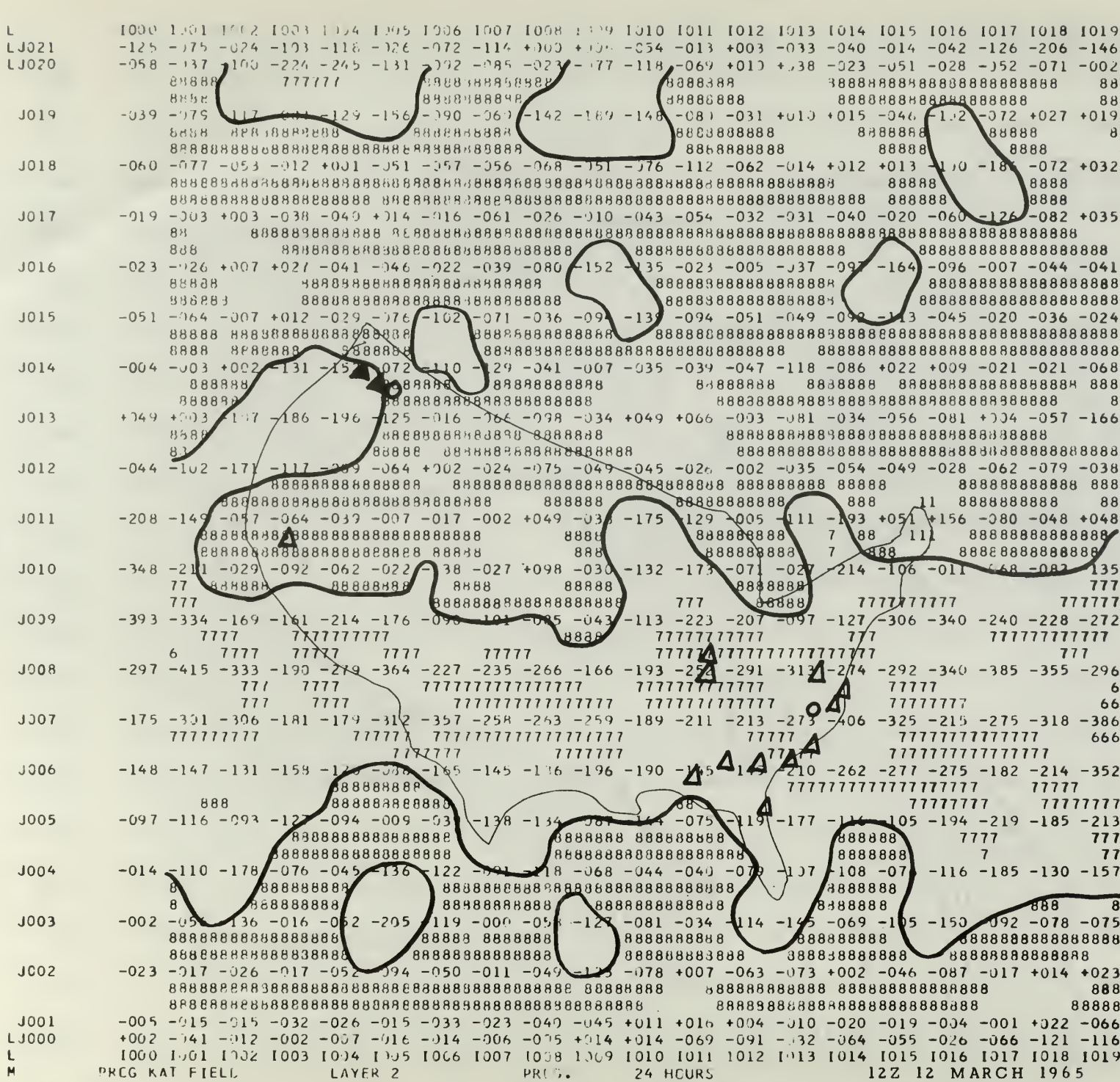
I000 I001 I002 I003 I004 I005 I006 I007 I008 I009 I010 I011 I012 I013 I014 I015 I016 I017 I018 I019 I020 I021
LJ021 -125 -075 -024 -103 -118 -026 -072 -114 +000 +000 -054 -013 +003 -033 -040 -014 -042 -126 -206 -146 +012 -034
LJ020 -058 -037 -100 -224 -245 -131 -092 -085 -023 -077 -118 -069 +010 +038 -023 -051 -028 -052 -071 -002 -043 -070
J019 -039 -079 -117 -041 -129 -156 -090 -060 -142 -189 -148 -081 -031 +010 +015 -046 -102 -072 +027 +019 -049 -008
J018 -060 -077 -053 -012 +001 -051 -057 -056 -068 -151 -076 -112 -062 -014 +012 +013 -100 -184 -072 +032 +008 -038
J017 -019 -003 +003 -038 -049 +014 -016 -061 -026 -010 -043 -054 -032 -031 -040 -020 -060 -126 -082 +035 +037 -063
J016 -023 -026 +007 +027 -041 -046 -022 -039 -080 -152 -135 -023 -005 -037 -097 -164 -096 -007 -044 -041 -017 -029
J015 -051 -064 -007 +012 -029 -076 -102 -071 -036 -094 -139 -094 -051 -049 -098 -113 -045 -020 -036 -024 -037 -055
J014 -004 -003 +002 -131 -152 -072 -110 -129 -041 -007 -035 -039 -047 -118 -086 +022 +009 -021 -021 -068 -012 -016
J013 +049 +003 -107 -186 -196 -125 -016 -066 -098 -034 +049 +066 -003 -081 -034 -056 -081 +004 -057 -166 -070 -008
J012 -044 -102 -171 -117 -089 -064 +002 -024 -075 -049 -045 -026 -002 -035 -054 -049 -028 -062 -079 -038 -129 -266
J011 -208 -149 -057 -064 -039 -007 -017 -002 +049 -038 -175 -129 -005 -111 -193 +051 +156 -080 -048 +048 -189 -390
J010 -348 -211 -029 -092 -062 -022 -138 -027 +098 -030 -132 -173 -071 -027 -214 -106 -011 -068 -082 -135 -242 -284
J009 -393 -334 -169 -161 -214 -176 -098 -101 -085 -043 -113 -223 -207 -097 -127 -306 -340 -240 -228 -272 -272 -290
J008 -297 -415 -333 -190 -279 -364 -227 -235 -266 -166 -193 -254 -291 -313 -274 -292 -340 -385 -355 -296 -411 -463
J007 -175 -301 -306 -181 -179 -312 -357 -258 -263 -259 -189 -211 -213 -273 -406 -325 -215 -275 -318 -386 -494 -388
J006 -148 -147 -131 -158 -140 -138 -165 -145 -136 -196 -190 -145 -149 -210 -262 -277 -275 -182 -214 -352 -321 -206
J005 -097 -116 -093 -127 -094 -009 -038 -138 -134 -081 -144 -075 -119 -177 -116 -105 -194 -219 -185 -213 -240 -167
J004 -014 -110 -178 -076 -045 -136 -122 -101 -118 -068 -044 -040 -078 -107 -108 -078 -116 -185 -130 -157 -226 -121
J003 -002 -056 -136 -016 -062 -205 -119 -000 -058 -127 -081 -034 -114 -145 -069 -105 -150 -092 -078 -075 -025 -049
J002 -023 -017 -026 -017 -052 -094 -050 -011 -049 -113 -078 +007 -063 -073 +002 -046 -087 -017 +014 +023 -018 -071
J001 -005 -015 -015 -032 -026 -015 -033 -023 -040 -045 +011 +016 +004 -010 -020 -019 -004 -001 +022 -066 -150 -107
LJ000 +002 -041 -012 -002 -007 -016 -014 -006 -075 +014 +014 -069 -091 -032 -064 -055 -026 -066 -121 -116 -056 -041
I000 I001 I002 I003 I004 I005 I006 I007 I008 I009 I010 I011 I012 I013 I014 I015 I016 I017 I018 I019 I020 I021
PROG KAT FIELD LAYER 2 PROG. 24 HOURS 12Z 12 MARCH 1965

TABLE 1

AIRCRAFT TURBULENCE CRITERIA

| CATEGORY | DEFINITION |
|---|---|
| LIGHT | A turbulent condition during which occupants may be required to use seat belts, but objects in the aircraft remain at rest. |
| MODERATE | A turbulent condition in which occupants require seat belts and occasionally are thrown against the belt. Unsecured objects in aircraft move about. |
| SEVERE | A turbulent condition in which the aircraft momentarily may be out of control. Occupants are thrown violently against the belt and back into the seat. Objects not secured in the aircraft are tossed about. |
| EXTREME | A rarely encountered turbulent condition in which the aircraft is violently tossed about, and is practically impossible to control. May cause structural damage to the aircraft. |

| FIELDS | DATE | TIME | LAYER | TOTAL # OF OCCR | % CORR | L to M | | M | | M to S | | S | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | # OCCR | # CORR | # OCCR | # CORR | # OCCR | # CORR | # OCCR | # CORR |
| LAPLACIAN OF VORTICITY | 10 MAR 65 | 00Z | I | 19 | 79 | 11 | 7 | 6 | 5 | 2 | 1 | 0 | 0 |
| VERTICAL GRADIENT OF THERMAL WIND | " | " | " | " | 63 | 11 | 8 | 6 | 4 | 2 | 0 | 0 | 0 |
| KINETIC ENERGY | " | " | " | " | 26 | 11 | 3 | 6 | 2 | 2 | 0 | 0 | 0 |
| KAT FIELD | " | " | " | " | 32 | 11 | 5 | 6 | 1 | 2 | 0 | 1 | 0 |
| LAPLACIAN OF VORTICITY | 10 MAR 65 | " | II | 42 | 67 | 22 | 16 | 16 | 8 | 4 | 4 | 0 | 0 |
| VERTICAL GRADIENT OF THERMAL WIND | " | " | " | " | 90 | 22 | 22 | 16 | 12 | 4 | 4 | 0 | 0 |
| KINETIC ENERGY | " | " | " | " | 86 | 22 | 19 | 16 | 13 | 4 | 4 | 0 | 0 |
| KAT FIELD | " | " | " | " | 76 | 22 | 17 | 16 | 12 | 4 | 3 | 0 | 0 |
| LAPLACIAN OF VORTICITY | 10 MAR 65 | 12Z | I | 14 | 71 | 6 | 5 | 5 | 5 | 3 | 3 | 0 | 0 |
| VERTICAL GRADIENT OF THERMAL WIND | " | " | " | " | 57 | 6 | 3 | 5 | 2 | 3 | 3 | 0 | 0 |
| KINETIC ENERGY | " | " | " | " | 93 | 6 | 6 | 5 | 5 | 3 | 2 | 0 | 0 |
| KAT FIELD | " | " | " | " | 71 | 6 | 6 | 5 | 4 | 3 | 0 | 0 | 0 |
| LAPLACIAN OF VORTICITY | 10 MAR 65 | " | II | 21 | 71 | 15 | 9 | 6 | 6 | 0 | 0 | 0 | 0 |
| VERTICAL GRADIENT OF THERMAL WIND | " | " | " | " | 90 | 15 | 13 | 6 | 6 | 0 | 0 | 0 | 0 |
| KINETIC ENERGY | " | " | " | " | 90 | 15 | 13 | 6 | 6 | 0 | 0 | 0 | 0 |
| KAT FIELD | " | " | " | " | 90 | 15 | 13 | 6 | 5 | 0 | 0 | 0 | 0 |

TABLE 2

| FIELDS | DATE | TIME | LAYER | TOTAL # OF OCCR | % CORR | L to M | | M | | M to S | | S | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | # OCCR | # CORR | # OCCR | # CORR | # OCCR | # CORR | # OCCR | # CORR |
| LAPLACIAN OF VORTICITY | 11 MAR 65 | 00Z | I | 40 | 68 | 21 | 10 | 13 | 11 | 5 | 5 | 1 | 1 |
| VERTICAL GRADIENT OF THERMAL WIND | " | " | " | " | 100 | 21 | 21 | 13 | 13 | 5 | 5 | 1 | 1 |
| KINETIC ENERGY | " | " | " | " | 67 | 21 | 15 | 13 | 8 | 5 | 4 | 1 | 0 |
| KAT FIELD | " | " | " | " | 63 | 21 | 9 | 13 | 9 | 5 | 5 | 1 | 1 |
| LAPLACIAN OF VORTICITY | 11 MAR 65 | 00Z | II | 51 | 71 | 31 | 21 | 16 | 11 | 4 | 4 | 0 | 0 |
| VERTICAL GRADIENT OF THERMAL WIND | " | " | " | " | 98 | 31 | 30 | 16 | 16 | 4 | 4 | 0 | 0 |
| KINETIC ENERGY | " | " | " | " | 88 | 31 | 29 | 16 | 12 | 4 | 4 | 0 | 0 |
| KAT FIELD | " | " | " | " | 82 | 31 | 25 | 16 | 13 | 4 | 4 | 0 | 0 |
| LAPLACIAN OF VORTICITY | 11 MAR 65 | 12Z | I | 22 | 77 | 14 | 9 | 6 | 6 | 1 | 1 | 1 | 1 |
| VERTICAL GRADIENT OF THERMAL WIND | " | " | " | " | 86 | 14 | 11 | 6 | 6 | 1 | 1 | 1 | 1 |
| KINETIC ENERGY | " | " | " | " | 64 | 14 | 10 | 6 | 4 | 1 | 0 | 1 | 0 |
| KAT FIELD | " | " | " | " | 50 | 14 | 8 | 6 | 5 | 1 | 0 | 1 | 0 |
| LAPLACIAN OF VORTICITY | 11 MAR 65 | 12Z | II | 5 | 60 | 3 | 3 | 2 | 0 | 0 | 0 | 0 | 0 |
| VERTICAL GRADIENT OF THERMAL WIND | " | " | " | " | 80 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| KINETIC ENERGY | " | " | " | " | 60 | 3 | 2 | 2 | 1 | [illegible] | 0 | [illegible] | [illegible] |
| KAT FIELD | " | " | " | " | 40 | 3 | 1 | 2 | 1 | [illegible] | [illegible] | [illegible] | [illegible] |

TABLE 3

| FIELDS | DATE | TIME | LAYER | TOTAL # OF OCCR | % CORR | L to M | | M | | M to S | | S | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | # OCCR | # CORR | # OCCR | # CORR | # OCCR | # CORR | # OCCR | # CORR |
| LAPLACIAN OF VORTICITY | 12 MAR 65 | 00Z | I | 27 | 52 | 11 | 7 | 11 | 6 | 2 | 1 | 3 | 1 |
| VERTICAL GRADIENT OF THERMAL WIND | " | " | " | " | 92 | 11 | 10 | 11 | 10 | 2 | 2 | 3 | 3 |
| KINETIC ENERGY | " | " | " | " | 70 | 11 | 6 | 11 | 10 | 2 | 1 | 3 | 1 |
| KAT FIELD | " | " | " | " | 59 | 11 | 7 | 11 | 7 | 2 | 1 | 3 | 1 |
| LAPLACIAN OF VORTICITY | 12 MAR 65 | 00Z | II | 19 | 53 | 4 | 2 | 9 | 5 | 5 | 2 | 1 | 1 |
| VERTICAL GRADIENT OF THERMAL WIND | " | " | " | " | 89 | 4 | 3 | 9 | 8 | 5 | 5 | 1 | 1 |
| KINETIC ENERGY | " | " | " | " | 63 | 4 | 1 | 9 | 5 | 5 | 5 | 1 | 1 |
| KAT FIELD | " | " | " | " | 48 | 4 | 2 | 9 | 5 | 5 | 2 | 1 | 1 |
| LAPLACIAN OF VORTICITY | 12 MAR 65 | 12Z | I | 26 | 77 | 15 | 10 | 11 | 8 | 0 | 0 | 0 | 0 |
| VERTICAL GRADIENT OF THERMAL WIND | " | " | " | " | 100 | 15 | 15 | 11 | 11 | 0 | 0 | 0 | 0 |
| KINETIC ENERGY | " | " | " | " | 88 | 15 | 13 | 11 | 10 | 0 | 0 | 0 | 0 |
| KAT FIELD | " | " | " | " | 92 | 15 | 14 | 11 | 10 | 0 | 0 | 0 | 0 |
| LAPLACIAN OF VORTICITY | 12 MAR 65 | 12Z | II | 16 | 81 | 12 | 9 | 2 | 2 | 2 | 2 | 0 | 0 |
| VERTICAL GRADIENT OF THERMAL WIND | " | " | " | " | 94 | 12 | 11 | 2 | 2 | 2 | 2 | 0 | 0 |
| KINETIC ENERGY | " | " | " | " | 94 | 12 | 11 | 2 | 2 | 2 | 2 | 0 | 0 |
| KAT FIELD | " | " | " | " | 87 | 12 | 11 | 2 | 1 | 2 | 2 | 0 | 0 |

TABLE 4

| | All Categories | LIGHT TO MODERATE | MODERATE | MODERATE TO SEVERE | SEVERE |
|---|---|---|---|---|---|
| TOTAL NUMBER OF KAT OCCURRENCES | 302 | 165 | 103 | 28 | 6 |
| (10 MARCH 1965 TO 12 MARCH 1965) | | | | | |
| | | | | | |
| PERCENT CORRELATION ( BY FIELD AND CATEGORY ) | | | | | |
| LAPLACIAN OF VORTICITY | | 65 | 71 | 71 | 67 |
| VERTICAL GRADIENT OF THERMAL WIND | | 90 | 89 | 93 | 100 |
| KINETIC ENERGY | | 70 | 76 | 78 | 33 |
| KAT FIELD | | 72 | 70 | 60 | 50 |
| | | | | | |
| PERCENT CORRELATION ( BY FIELD ) | | | | | |
| LAPLACIAN OF VORTICITY | 68 | | | | |
| VERTICAL GRADIENT OF THERMAL WIND | 90 | | | | |
| KINETIC ENERGY | 76 | | | | |
| KAT FIELD | 70 | | | | |

TABLE 5

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13. ABSTRACT

There is much disagreement as to (a) what causes clear air turbulence (turbulence which is not in or near convective clouds and is above 15,000 feet in altitude) and (b) which meteorological parameters can be used to detect and forecast its occurrence. The approach to this problem has been to relate not one parameter to clear air turbulence but various parameters. By summing these parameters areas can be defined where there is a high probability of encountering clear air turbulence. Each parameter has been based on a statistical study which found a relationship with clear air turbulence. The parameters used were horizontal and vertical shear, curvature, kinetic energy and their derivatives. The numerical forecasting program proposed here can be extended to the stratosphere when more reliable height and temperature fields are available. This program will have much more significance when intermediate forecast height fields, temperature fields and a grid of much smaller mesh length are available.

DD FORM 1 JAN 64 1473

| 14. KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Turbulence | | | | | | |
| Clear Air Turbulence | | | | | | |